

■ ROBOTICS ■ MICROCONTROLLERS ■ COMPUTER CONTROL ■ SPACE

NUTS
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AUGUST 2006

EVERYTHING FOR ELECTRONICS

Cosmac ELF Turns

30!

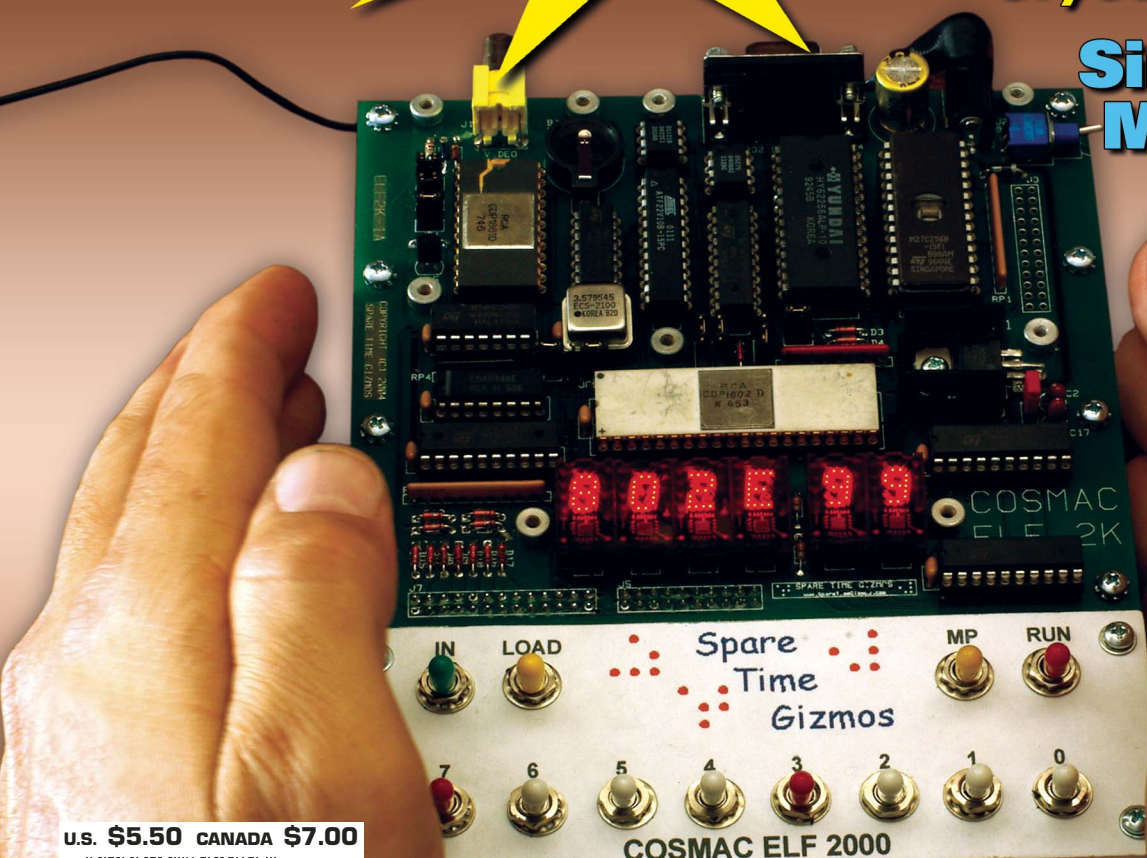
Testing HD Radio

Don't Blow a Fuse!

Understanding Digital Logic ICs

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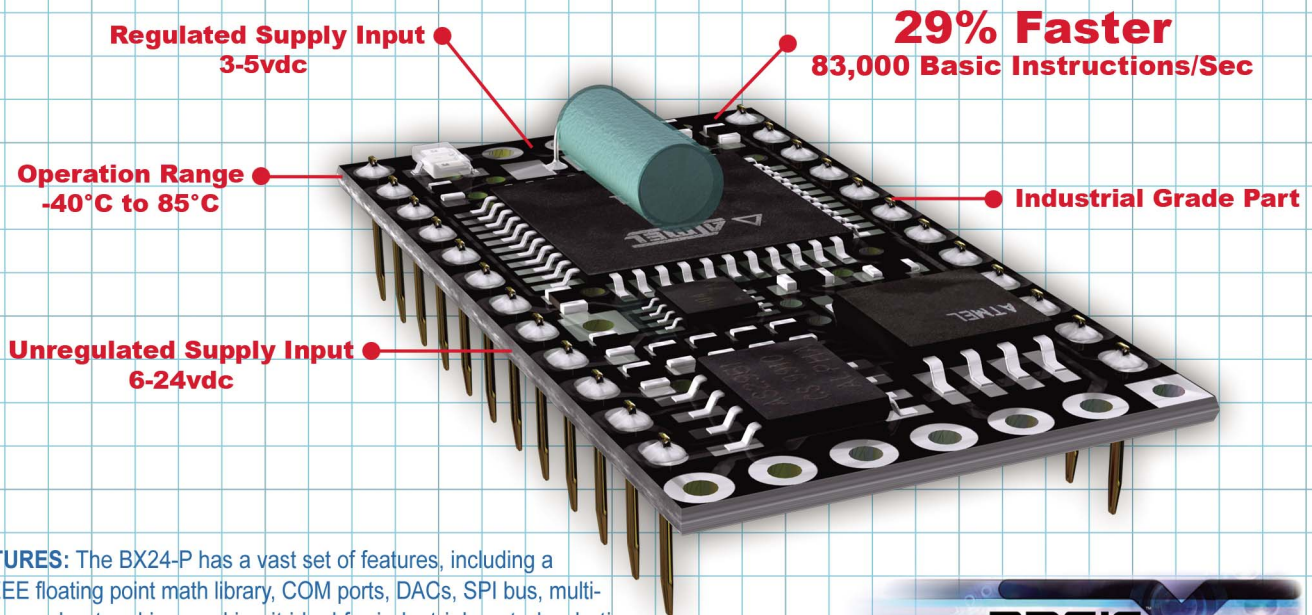
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Announcing the BasicX - BX24-P

The *fastest* Basic programmable microcontroller...

Just Got BETTER for the same price \$49.95



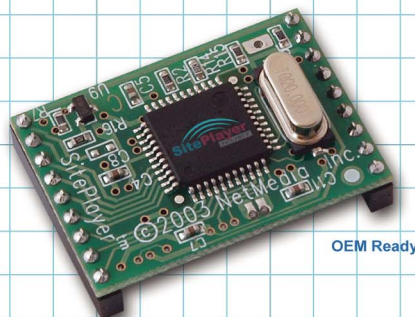
FEATURES: The BX24-P has a vast set of features, including a full IEEE floating point math library, COM ports, DACs, SPI bus, multi-tasking and networking, making it ideal for industrial control, robotics, automated testing equipment and home automation. BX24-P is able to monitor and control all your switches, timers, motors, sensors, relays, and more. Measuring just 1.25" X .75", OEMs can easily see the value of this little powerhouse.



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Announcing SitePlayer Telnet™ Serial to Ethernet Data Converter

SPT1 – SitePlayer Telnet™ OEM module
ONLY \$29.95

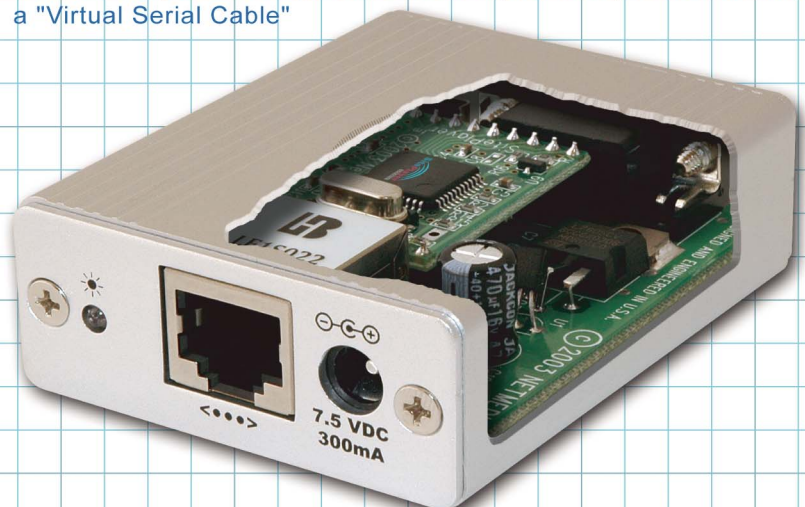


Features - 10BaseT, ARP, UDP, TCP/IP, DHCP, Link Local, Bonjour, ICMP Ping, HTTP, Telnet, Daytime protocol, Discard protocol, 4 IP addresses, Serial AT command mode for external processor control of Ethernet sessions.

Enable your serial devices to communicate across Ethernet

The SitePlayer Telnet module gives OEM's and product designers the ability to quickly and cost-effectively bring their products to market

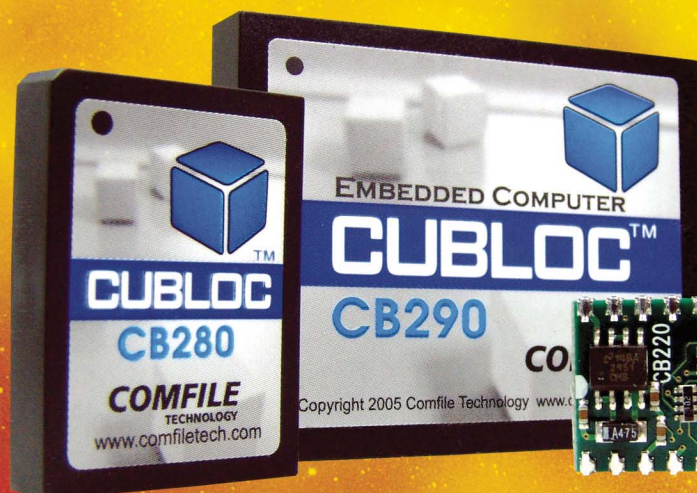
Two SitePlayer Telnet systems can easily be configured to create a "Virtual Serial Cable"



SPTS – SitePlayer Telnet™ System, now available directly from NetMedia at an **Introductory price of \$79.95**



PLC on chip with BASIC



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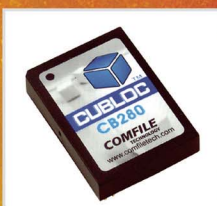
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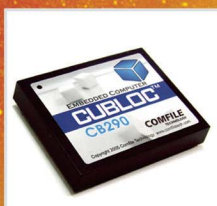
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CB220
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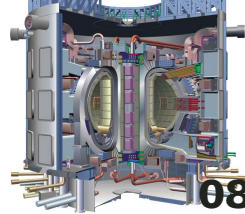
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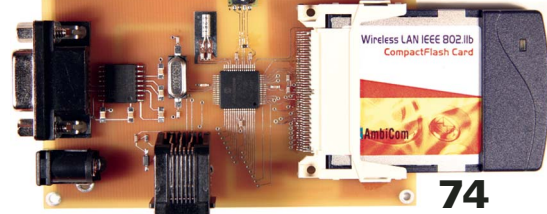
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NUTS AND VOLTS

AUGUST 2006

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Use your guitar to play your computer, so to speak.

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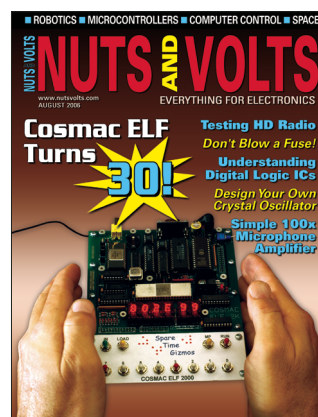
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Construct an Elf clone using modern, easy-to-get parts.

■ By Robert Armstrong

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Unlike its more famous cousin — the Altair 8800 — the COSMAC Elf was a microcomputer project that anybody could afford.



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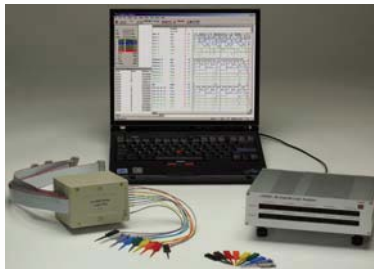


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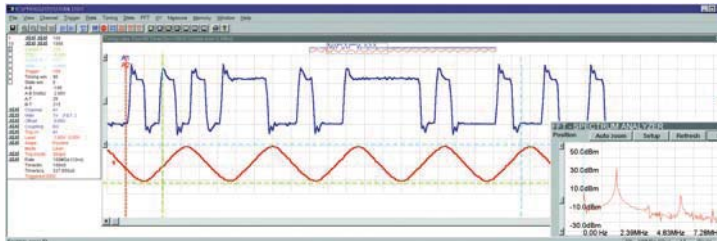
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READER FEEDBACK

NUTS AND VOLTS
EVERYTHING FOR ELECTRONICS

ON THE BANDWAGON

I'm a long time subscriber and I don't write often, but it's time to catch up. Thanks for the new size format. Everyone else said it better than I would, but I still wanted to add my, "Me too." Thanks for getting rid of the fuzzball throughout. It too was overdue. Thanks for ending, "In the Trenches." It was great advice, but maybe it needs to be in a business magazine.

Thanks to the front office folks who always get my lost issues out to me, changes of address, and

subscription renewals year after year. They earned their praise, too. And thanks especially for yet another, "How to blink an LED with a microcontroller" article. Chuck Hellebuyck is right on the mark. In short, I've seen a lot of changes over years in NV and I like the direction you're going.

Keep up the great work. I can't wait for the next issue!

Robert Swain
San Diego, CA

PHIL-OSOPHICAL QUESTION

I've read your Personal Robotics columns on the Zigbee development boards and I'm looking at using the Panasonic version (due to the size of the unit).

Did you use the BDM hardware or just the serial port? If you just used the serial port, how did you get the module into bootloader mode?

Thanks for your help.

Amy Bierce

Writer Response: The Zigbee boards we used in the articles were, as you know, manufactured by

Continued on page 50

READER SURVEY WINNER

Congratulations go to
RON GIUNTINI
of San Francisco, CA.
Ron is the winner
of the TOM TOM
GPS Navigation System.



**DON'T TELL ME YOU'VE BEEN READING THAT
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by J. Shuman

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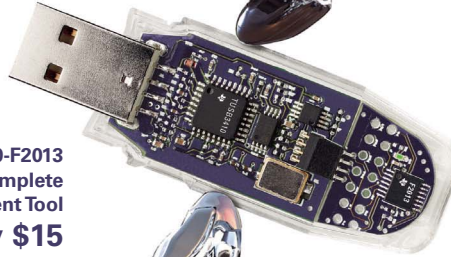
Debbie Stauffacher

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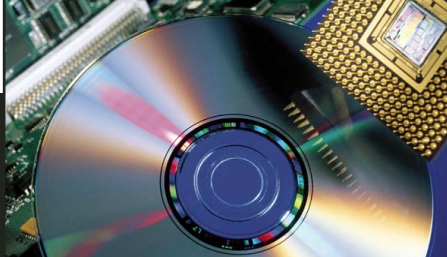
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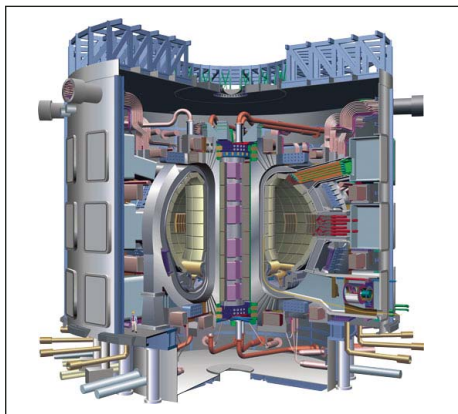
 **TEXAS INSTRUMENTS**



■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

FUSION EXPERIMENT CONSTRUCTION BEGINS



■ Artist's rendition of the ITER fusion device. Published with permission of ITER.

With the world's need for a clean, cheap, and safe source of energy being more evident every day, it seems timely that an international effort to build the International Thermonuclear Experimental Reactor (ITER) has been launched. The United States, China, the European Union, India, Japan, the Republic of Korea, and the Russian Federation are joint sponsors of the project, which aims to experimentally generate up to 500 million watts of energy. The installation will be located in Cadarache, in the south France.

The device itself is based on the tokamak, in which a hydrogen plasma is confined in a doughnut-shaped vessel using a magnetic field and heated to something over 100 million degrees Celsius. (The term, in case you are wondering is a transliteration from Russian and is derived from words meaning "toroidal chamber in magnetic coils. It was invented in the 1950s by Andrei Sakharov and Igor Tamm.) There are several of these scattered around the world, but ITER is billed as the largest fusion-energy experiment ever conducted and will cost an estimated \$2,755 million. It is projected that the first

round of plasma generation will not be possible until the end of 2016, so don't expect to charge up your electric car with fusion-generated electricity right away. For details, visit www.iter.org

TINY HYDROGEN SENSOR DEVELOPED



■ Close-up of a tiny hydrogen sensor developed at the University of Florida.

While we're waiting for fusion to solve all of our energy problems, quite a few people are talking about hydrogen itself as the "fuel of the future" and focusing on its use in fuel cells. In fact, the President launched the \$1.2 billion Hydrogen Fuel Initiative in 2003 to study ways to make the technology commercially feasible. It's not clear yet where we are going to get enough of the stuff to create the "hydrogen economy," but if it happens, we will face the little problem that the gas is odorless, invisible, and explosive, so detecting leaks is rather important but previously not all that easy.

Now, a team of engineering faculty and graduate students at the University of Florida (www.ufl.edu) has come up with a tiny, cheap sensor that can detect hydrogen leaks and set off an alarm via a wireless connection. It is referred to as a "sensor node," because it is intended to work with dozens or even hundreds more. Most interestingly, it can be powered by an internal "piezoelectric vibrational energy har-

vesting system," which basically generates power from small vibrations in its operational environment. According to UF, future versions could operate continuously without batteries or maintenance when attached to automobiles, motors, or anything else that vibrates.

UF materials, electrical, and chemical engineering researchers all had a hand in crafting the node. The materials and chemical researchers came up with the sensor, which is based on zinc oxide nanorods, which are basically whiskers of zinc oxide that a tiny electrical current passes through. The more hydrogen surrounding the whiskers, the more conductive they become, providing a way to measure the ambient hydrogen in the air. Lab tests show it capable of detecting as little as 10 ppm of the gas (well below the explosive concentration level) and transmitting the information to a central base station located about 20 m away.

The device was actually developed as part of the NASA Hydrogen Research Program. The space shuttle uses liquid hydrogen as fuel, so the sensors will be used to improve safety and reliability in shuttle systems. However, they could have a wide variety of other applications.

COMPUTERS AND NETWORKING

WEBSITE ADDRESSES U3 FLASH DRIVES

If you're not familiar with U3 Flash drive technology, you might find it worth paying a visit to U3-Info (www.U3-Info.com) — a new community forum on the subject, developed for both users and software developers. With the U3 concept, you don't merely use the drive to move data from one computer to another, you actually load applications and documents on the

■ U3 Flash drives — such as the SanDisk Cruiser — allow “smart” operation on a range of computers.



PHOTO COURTESY OF U3-INFO.

drive and boot them up on any handy machine, making the drive essentially a portable version of your computer minus the computer.

You can take your browser and bookmarks, email program, word processor, or whatever with you wherever you go. While it appears that most of the drives are compatible with Windows® only, SanDisk (www.sandisk.com) sells the Cruiser® Micro USB Flash Drive, with 256 MB capacity, for \$24.95, and it is said to be compatible with Windows ME, 2000, and XP, Mac OS 9.1.x+ and OS X v10.1.2+, and Certified Windows XP.

U3-Info offers various articles and other information on the hardware and software, plus a list of companies that sell U3 products. And, in case you were wondering, no, you can't upgrade your existing Flash drive to U3 level. Sorry, but the hardware is different.

2.5-INCH DRIVE OFFERS HIGH RELIABILITY

PHOTO COURTESY OF SEAGATE TECHNOLOGY LLC.



■ Seagate's new Savvio 10K.2 drive provides reduced power consumption and high reliability.

On a more traditional level is the new Savvio 10K.2 disk drive, which is the second-generation 2.5-inch enterprise-class storage device from Seagate (www.seagate.com). Available with up to 146 GB capacity, it uses 15 percent less power than its predecessor and offers what Seagate claims is a world record in reliability: 1.6 million hours MTBF. That comes out to a little better than 182 years, and there's a good chance you won't be using it that long, but it is a pretty impressive number. The drive is aimed at the creation of new types of

storage systems, including blade servers, 1U servers with full RAID 5 capability, and larger rack servers that need the highest possible performance density. Interfaces include 3 GB serial attached SCSI (SAS) and 4 GB fiber channel. Price information was unavailable at the time of this writing, but the previous 73.4 GB version sold for between \$464 and \$565, according to CNET (www.cnet.com), which might provide a hint.

SOFTWARE PROVIDES REAL-TIME AUTHENTICATION

Unless you own or run a bank, you won't be buying the product, but the Falcon One for Online Access product line, recently introduced by Fair Issac Corp. (www.fairisaac.com), may affect you anyway. Billed as a comprehensive system for protecting online financial transactions, it provides neural network-based transaction monitoring by learning customer behavior patterns and recognizing suspicious transactions, including activities that include online, debit, branch, and credit transactions.

By “suspicious,” we're talking about whether you log on from your usual IP address, the clock setting on your computer, and even the way you type and operate your mouse. You will probably be unaware that the system is watching you unless your activities reach a certain threshold of fraud risk, at which point the bank might send a password to your known email address or cell phone and ask you to enter it before continuing the session. It may seem slightly like Big Brother is watching you, but it might be a reasonable trade-off for protecting your assets.

CIRCUITS AND DEVICES ONE SMOKING CAMERA

According to a recent announcement from the US Consumer Product Safety Commission

■ HP's R707 camera is recalled because of fire hazard.



PHOTO COURTESY OF HEWLETT-PACKARD.

(www.cpsc.gov), Hewlett-Packard has agreed to a voluntary recall of its Photosmart R707 digital cameras, of which it has sold about 224,000 units in the USA and 670,000 worldwide. Apparently, when the camera is connected to an AC adaptor or docking station, it can cause some nonrechargeable batteries — and specifically the Duracell CP-1 — to overheat and pose a fire hazard.

The Chinese-built camera has not actually caused physical harm to anyone, but owners are advised to stop using the cameras until they have been upgraded with a firmware update that eliminates the problem. The good news is that you can do it yourself simply by logging onto www.hp.com and clicking on the “Replacement programs & recalls” link.

FUSED CAPACITOR PROVIDES EXTRA PROTECTION

If your latest design is for something that is particularly sensitive to short-circuit failures, take a look at the TBW series tantalum fused capacitors from AVX Corp. (www.avxcorp.com). Using a thin film technology, the device includes an internal fuse to protect against short circuits, and it also offers lower ESR limits than many other caps.

The primary applications for the capacitor include any military or aerospace circuitry where derating is at marginal levels and reliability relating to voltage breakdown is a concern. Capacitance values range from 4.7 μ F to 47 μ F, with a capacitance tolerance of $\pm 10\%$ to $\pm 20\%$. The series is rated for a temperature range -55 to +125°C and is available with voltage ratings up to 50 VDC.

AUTODRIVE DEVELOPED FOR CELL PHONE CAMERAS

This may not be the most momentous development in electronics, but for people who use the cameras on their cell phones, this new feature could eliminate a minor source of annoyance. Samsung Electro-Mechanics (www.sem).

samsung.com) has developed a device that rotates the camera between landscape and portrait at the push of a button, thus eliminating the need to rotate the entire phone. The rotation takes only 0.5 sec, and the drive mechanism — which draws just 60 mA — is designed to last through 70,000 cycles.

Samsung surveyed 500 users and determined that a majority of them would like this feature, so presumably they know something that isn't immediately obvious to all of us. The device should start appearing in mobile phones soon. Other apparently insignificant devices developed by the company include mechanisms for automatically opening and closing mobile phones, including an auto-folder module and an auto-slide unit. **NV**

INDUSTRY AND THE PROFESSION

SUN ANNOUNCES REORGANIZATION PLAN

Late in May, Sun Microsystems, Inc. (www.sun.com), announced that the board of directors had approved a "growth plan" calling for "increasing investment in core technology and channel resources, while accelerating acquisition synergies and disinvestments in non-core processes and research and development activities." (If you read that

several times, it still won't contain any meaning.) Getting down to specifics, it looks like Sun will lay off 4,000 to 5,000 employees over a six-month period, sell its Newark campus, and abandon a leased facility in Sunnyvale, CA. The Menlo Park and Santa Clara operations will continue. The expected result is an annual cost savings of between \$480 million and \$590 million, with the full benefit to show up in Q4 of fiscal 2007.

NEW STANDARD FOR "GREEN" COMPUTERS

The US Environmental Protection Agency (www.epa.gov), in conjunction with the Institute for Electrical and Electronics Engineers Standards Association (standards.ieee.org), recently announced a new voluntary environmental performance standard to help large computer buyers make environmentally sound purchases. The new IEEE standard, IEEE 1680™, "Standard for Environmental Assessment of Personal Computer Products," was developed by a working group composed of representatives from the electronics industry, environmental advocacy groups, state and local purchasing officials, electronics recyclers, and academics. It was approved through the consensus-based IEEE standards development process and is recognized by the American National Standards Institute (www.ansi.org).

IEEE 1680 and its product registration and verification system are part of the Electronic Products Environmental Assessment Tool (EPEAT), which is managed by the Green Electronics Council under a grant from the EPA. The council will maintain a registry of computer products that meet IEEE 1680 criteria at www.epeat.net. The Council will verify that the information provided by manufacturers is accurate and up to date.

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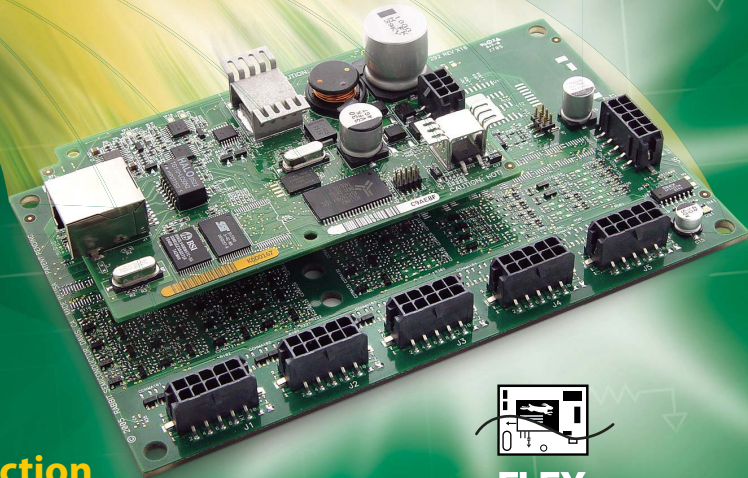
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■ BY LOUIS E. FRENZEL

TESTING HD RADIO

BACK IN THE APRIL '04 ISSUE OF *NUTS & VOLTS*, I introduced some of you to digital radio broadcasting. It was mostly a theoretical discussion because there were few stations on the air and even fewer radios available. But today, digital radio — now called HD Radio — is actually here.

Not only are there hundreds of stations on the air, but you can actually buy a radio to hear them. I've been testing a couple of HD radios lately to see if they live up to the hype and benefits attributed to them. Here is my report on this new consumer electronic product category.

HOW IT WORKS

For those of you who are not familiar with digital HD radio, let me give you a quick breakdown. First, this is not the same as satellite radio. You have probably heard of both Sirius and XM satellite radio. These are two digital radio services delivered directly from satellites. They operate in the 2.3 GHz band and are both subscription services. Sirius and XM both have over 100 channels of commercial free music, news, sports, humor, and other

programming. In the beginning, receivers were scarce, but now you can get satellite radios in most new cars as an option and there are numerous home and portable units, as well as after-market receivers you can get.

Overall, satellite radio has been a big success. Despite the \$10 to \$12 monthly fee, millions have subscribed. The audio quality is far superior to regular AM and FM radio and the programming is vast. Better still is the fact that you can receive the same program coast to coast in the US without ever changing the channel. You certainly cannot do that with AM and FM stations that fade out after a few miles while driving.

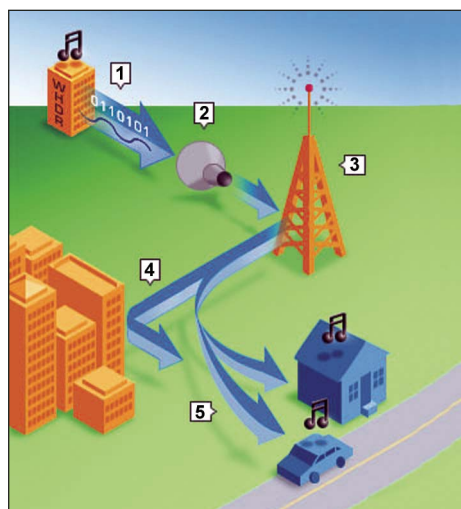
HD radio is supposedly the digital replacement for our legacy AM and FM analog broadcasts. It is intended to bring the benefits of digital to broadcast radio, namely less noise and fading and higher quality audio. The system approved by the FCC (Federal Communications Commission) is designed to operate concurrently with the regular analog AM and FM stations in the very same spectrum. If a station is transmitting the digital signal, and

you have an HD radio, you can get the digital signal. If you only have a traditional analog radio, not to worry, as you can still receive the regular AM or FM signal. Then, eventually, when almost everyone has an HD radio, the old analog broadcast signals can be turned off. Scary thought, huh?

The HD radio system was developed by iBiquity Digital Corporation and is known as In Band, On Channel (IBOC). It was officially approved in 2002, but it has taken years of additional development and investment to roll out the service. Today, there are over 600 stations in the US transmitting in HD format. Most of these are FM stations, but there are a good number of AM stations, as well. Go to www.ibiquity.com (under the HD Radio tab, select Stations On-the-Air) and check the list of stations for your state.

What the system does is to take the regular analog music or talk content and digitize it. Then it puts the digital data into an encoder that compresses it just like a cell phone digitizes your voice and compresses it. The purpose of the compression is to create a lower speed serial digital signal that will take up less radio spectrum space. The digitized signal is then used in a modulation process before it is combined with the analog signal and the combination sent to the transmitter. The signal is broadcast to home, car, and office (see Figure 1). Usually both the digital and analog content is the same. This is called the hybrid format of HD radio.

HD radio is supposed to solve



■ **FIGURE 1.** How HD radio works. Audio signal from studio is digitized and compressed (1) then put into packet format and converted to OFDM (2) for transmission by the radio station's regular transmitter (3). The signals travel directly and via reflected paths where noise is picked up along the way (4). The HD receiver sorts all the signals out to produce the stereo audio (5). Photo courtesy of iBiquity.

■ FIGURE 2. AM band spectrum of HD radio.

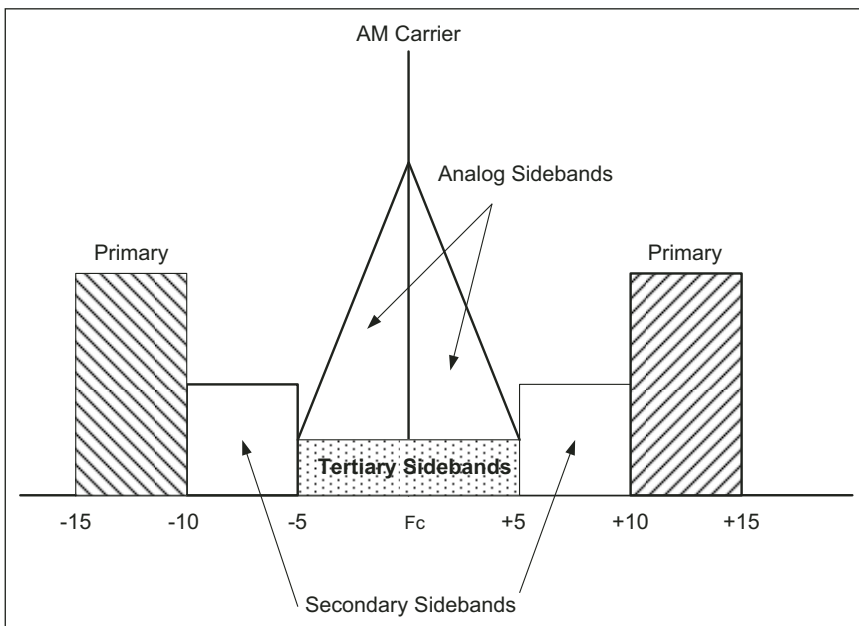
some of the key problems that still plague analog radio. Noise and static are the bane of AM radio. And fading is common, especially at night when long distance skip conditions come into play. FM pretty much is noise free because of its inherent insensitivity to amplitude variations. But operating in the VHF range (88 to 108 MHz), the signal is subject to multiple paths due to reflections. This also causes fading. Digital techniques pretty much take care of the noise for sure. Fading is also somewhat mitigated on FM, as well. However, fading on AM is not especially improved.

The greatest potential benefit of digital is greater fidelity. Most AM stations only transmit analog frequencies up to about 5 kHz and many cut off lower than that. This is definitely low-fi but most of AM radio is talk anyway, so we don't really notice this. FM radio transmits frequencies up to 15 kHz, truly hi-fi. On a good receiver with decent speakers, you can hear the fidelity. Digital is supposed to make this better. HD radio claims that AM will sound more like FM and FM will sound more like CD quality.

Figure 2 shows how HD radio adds the digital information to AM. The digital data appears in new sidebands above and below the regular analog sidebands which take up the 5 kHz segments directly above and below the carrier. HD radio extends the bandwidth of the AM signal from 10 kHz to a total of 30 kHz. If you recall, it takes quite a bit of bandwidth to transmit digital information. That is why the digital signal is compressed first.

There are actually two sets of digital sidebands. The primary sidebands extend from 10 kHz to 15 kHz above and below the carrier. The modulation technique is orthogonal frequency division multiplexing (OFDM). OFDM divides the compressed digital audio into multiple parallel streams of lower speed digital data and modulates them on up to 81 different carriers using 64 QAM (quadrature amplitude modulation). The secondary sidebands from 5 kHz to 10 kHz also use OFDM, but employ 16 QAM modulation. There are even some tertiary sidebands that are "under" the analog sidebands meaning they are in quadrature (90-degree shift) to the station carrier). What you end up with at the receiver is a 36 kbps digital bit stream for stereo AM. The maximum theoretical bandwidth is about 8 kHz. That is better than the 5 kHz of the analog signal, but few can notice any difference on voice.

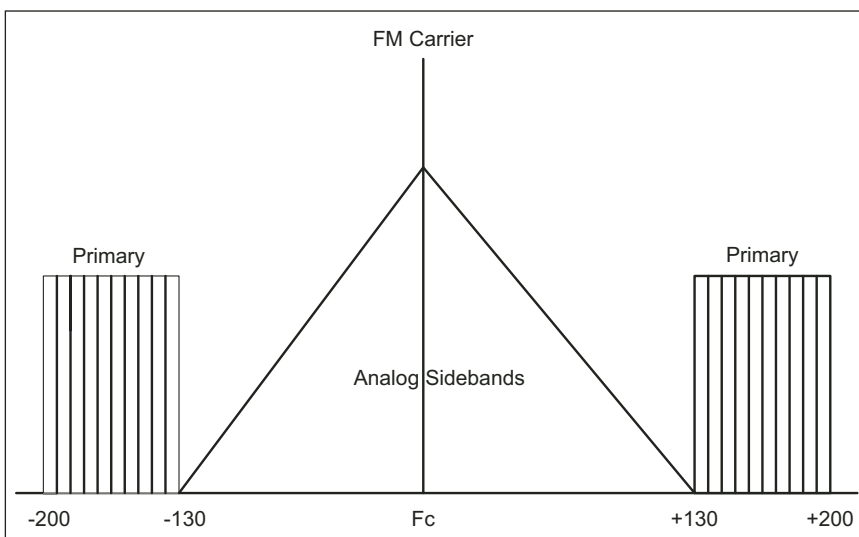
The biggest problem with HD AM radio is that the digital sidebands sometimes spill over into adjacent channels. The AM spectrum was laid out for 10 kHz station spacing. Nearby stations were not assigned frequen-



cies that close together but most radios can still pull in distant stations that may be operating on an adjacent channel. The digital sidebands produce a whining type of interference with the station, sometimes making it unintelligible. This is a horrible problem at night, so much so that the FCC has banned HD radio transmission in the AM bands after 6 pm.

The FM spectrum of HD radio is shown in Figure 3. It, too, places the compressed digital signal in extended upper and lower sidebands. The OFDM sidebands occupy the space from 130 kHz to 200 kHz range above and below the carrier for a total bandwidth of 400 kHz, double that of a regular analog FM broadcast. The resulting bit stream at the receiver is 96 kbps for stereo which theoretically should give CD quality audio. As for adjacent channel interference, it is less of a problem in the FM band especially if local stations are widely spaced. VHF FM signals rarely travel more than about 100 miles anyway so the interference problem essentially does not occur.

OFDM is a bloody complicated digital system. There



■ FIGURE 3. FM band spectrum of HD radio.



■ **FIGURE 4.** The Boston Acoustic Receptor Radio HD. One of the first — if not *the* first — table-top HD radios to hit the market. The unit is tiny (7.5" x 4" x 6") and comes with a separate stereo speaker and a remote control (not shown).

The first thing I did before buying these radios was to check to see how many HD stations were in my area. I

really is no analog equivalent. Instead, the encoding and decoding, modulation and demodulation is done with digital signal processing (DSP). A high speed DSP embedded controller at the transmitter runs an inverse fast Fourier transform (IFFT) algorithm to create the OFDM signal from the compressed digital audio. At the receiver, a DSP runs the fast Fourier transform (FFT) to demodulate the signal then to decompress it for application to digital-to-analog converters (DACs) that drive the audio amplifiers and speakers.

TESTING THE RADIOS

It took me a while to actually get my hands on a real (and affordable) HD radio. I have the Boston Acoustic Receptor Radio HD and the Radiosophy Multistream HD radio. Take a look at Figures 4 and 5. Both are desktop units for home operation. Some after-market auto radio HD radios are also available as are a few high end stereo component receivers. The initial price for these radios was about \$500, but they have come down now to about half that. I bet you could get one on the Internet for less than \$200 these days. That is still a high price for an AM/FM radio, digital or not. But prices will come down as volume increases.



went to the iBiquity website and looked that up. I was surprised to find four local stations and more on the way. These are FM stations. Closest AM HD stations are 75 miles away. I can get both during the day.

Is the quality better? All of you know that audio quality is pretty much a personal subjective thing. What may be good for one is not so good for another. Hearing frequency range also varies widely with individuals. What did I hear? Bottom line, on AM I really cannot tell the difference between the analog and digital versions. It is not necessarily better or worse, just similar. I did not have the test equipment to make any response tests so I am relying on my ears to tell the difference.

Perhaps the main thing I noticed is that the audio sounded muffled. I suspect that this is either a function of the receiver's audio response and speakers or caused by the compression. Any time you compress data that much it is difficult to recover it faithfully. Something is almost always lost in the translation process.

As for FM, the results are again similar. Frankly, I cannot tell the difference between the analog and digital versions of the FM signal. Both sound good. I can say that according to my ears, a CD still gives better fidelity than analog or HD FM radio. Again, I have to say that my guess is that it is the compression that is killing the fidelity. I think iBiquity knows this given that they have changed their compression algorithms several times during development.

It is tough to recover the full

■ **FIGURE 5.** The Radiosophy MultiStream HD radio. This cool design comes ready to receive the new multicast HD2 broadcasts.

content of an analog signal once it is compressed. For cell phones, intelligibility is the goal not fidelity. For both AM and FM, the compression is just too great for music. Heavy compression is necessary to get the signal into the assigned spectrum, but the quality of the audio is compromised by the compression, especially music. As comedian Dennis Miller says, "That's just my opinion, I could be wrong."

WHAT'S NEXT?

The radio stations are now heavily rolling out HD radio. They all have a heavy new investment in the transmitting equipment so are anxious for this to be a success. Most of them are now announcing the availability of their HD broadcasts on their analog stations with the hope of creating some converts. The newer version of HD radio called HD2 allows stations to divide up the OFDM carriers in such a way as to create two or more completely separate channels of audio. This means that a station can multicast, that is transmit two or more different programs in the same band. Most of the newer radios have this multiple channel decoding. In effect, it gives broadcasting more stations and more content for just about the same cost and no new spectrum. Check out your local situation there to see what's available.

Those of you wishing to convert to HD should go take a look at your local Best Buy, Circuit City, or other big electronics retailer to see what is available. And by all means take a listening test if you can. The iBiquity website also has a good listing of available equipment. The price is still high, but over time, it will come down. I know the iBiquity folks and the radio manufacturers would love to see HD radio in cars. So far it is not available except if you are willing to install an after-market unit. No doubt negotiations are going on with the auto manufacturers. But it remains to be seen just what future offerings may be. Will we get a choice of regular AM and FM plus HD, or AM and FM plus satellite, or all three?

If any of you have an HD radio or get it soon, let me know how you like it. **NV**

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■ BY JON WILLIAMS

STEPPING OUT WITH SPIN

ARE YOU READY TO GET SOME MOTORS SPINNING? Yeah, me too. As we saw last month with the BS1, to get more performance we have to think differently. With the Propeller chip, the entire paradigm is different and we are, in fact, forced to adapt. Sometimes change can be a bit uncomfortable, and changing from one programming style to another can be, well ... tough — if we let it. The funny thing for me is that I have done so much Spin programming the past year that when a client asked me to design a control product using an SX28, I had to shift gears back to a somewhat linear style. Yes, there were a few moments when I was wishing the customer had wanted to use the Propeller — my life might have been a little easier. Okay, then, how do we make the shift to Spin programming so that it becomes as comfortable as our old friend, PBASIC? For me, direct translation is the best way to start.

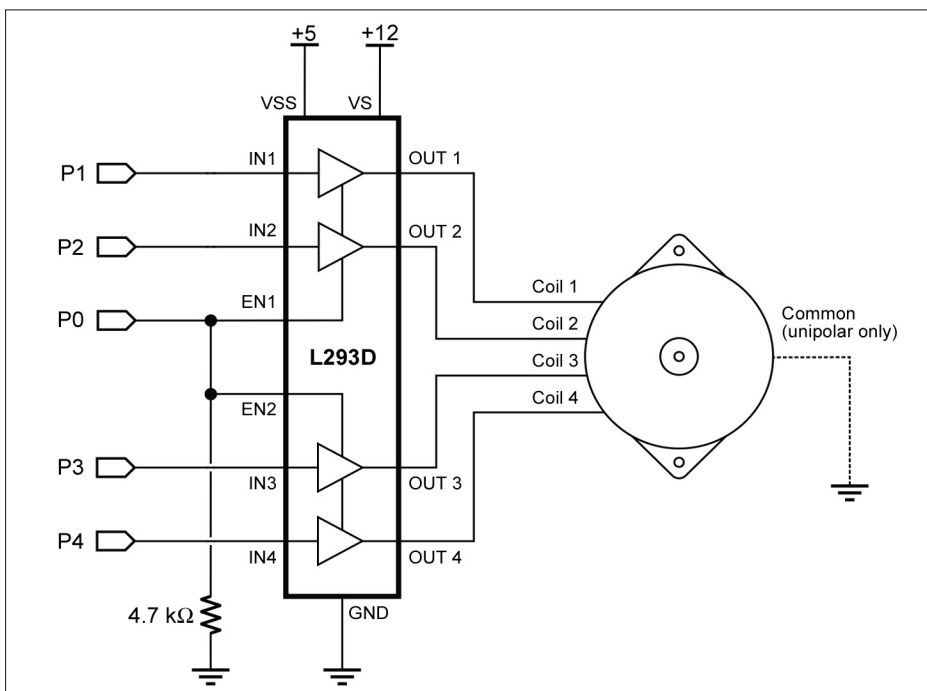
Perhaps it was me being too busy to notice, but I have this sudden awareness that controlling stepper motors is popular again. They are indeed very cool, finding use in hobby applications in everything from robot-

ics to home-built machine shop tools. And stepper control is actually quite easy as we've seen in the past. Let me qualify that controlling one stepper is quite easy; what if we want to control two — independently — for a robot,

or even three for some kind of XYZ machine platform? Yes, we could resort to a hardware stepper controller, but with the Propeller ... we don't have to anymore; we can code our own controller in Spin and manage as many motors as our I/O pins will allow.

First thing's first: Let's take the standard BS2 stepper demo program and translate it to Spin. This will do a couple things for us: 1) It lets us easily verify that the hardware is working with a simple program, and 2) It helps us make the translation from something we know to something we want to know.

Translation is on my mind lately as on my morning walks I listen to a Japanese language training CD. With the CD, I am taught new words and phrases, and then a bit later the "teacher" will ask, "How do you say ..." We can do this for ourselves. I'll be your teacher for this lesson; after you've mastered it, I suggest you follow this same process with your favorite BASIC Stamp programs.



■ FIGURE 1. Stepper with L293D.

FROM PBASIC TO SPIN

To start with, I'm going to translate the BS2 stepper motor demo code that is available on the Parallax website (and in the ZIP for this article on the *Nuts & Volts* website; www.nutsvolts.com). We'll go section-by-section making the translation from PBASIC to Spin.

Figure 1 shows the driver that we'll use to run the stepper motor — an L293D. I like this chip for driving steppers because it can drive unipolar (five or six wires) or bipolar (four wires) steppers with the same code. The only difference in the connections is that the unipolar motor has a common connection (or two) that goes to GND. Note that the original BS2 demo does not deal with the L293D enable pin, so we're going to add that to the program — it's a useful feature as it allows the stepper to "coast" when enable is not active.

A couple things about the L293D: You'll note that the logic supply (+5) is called VSS by the manufacturer — do not connect this pin to ground. The GND pins (4, 5, 12, and 13 on the DIP version) are for ground. The motor supply pin is called VS; this is pin 12 on the DIP. Before you make the connections for the L293D version you select, be sure to review the datasheet so that you make the correct connections. Also note that I've pulled the L293D Enable pins low through a 4.7K resistor; this disables the outputs when the control pin is disconnected or floating. If the Enable pins are allowed to float, the L293D outputs will be active.

Author's Note: The TI SN754410 can be used in place of the L293D.

Okay, let's start translating code. At the top of the BS2 program, we'll find the following definitions for the I/O connections and the number of steps the motor requires for a single revolution.

Phase	VAR	OUTB
StpsPerRev	CON	48

And here's how we're going to end up translating that code to Spin:

```
CON

_CLKMODE      = XTAL1 + PLL16X
_XINFREQ      = 5_000_000

EN            = 0
M1            = EN + 1
M4            = M1 + 3

STEPS_PER_REV = 48
```

Okay, so there's a little more work involved with the Spin definitions, but with that we get a whole lot more power and flexibility. We always start by defining **_CLKMODE** and **_XINFREQ**; the listing shows our "standard" selection of a 5 MHz clock input and the 16x PLL tap; this causes the chip to run maximum speed (80 MHz).

Next come the I/O pins. As noted earlier, we're adding

an Enable, along with the [contiguous] motor connections. With the Propeller, we have enormous flexibility with I/O. On the BASIC Stamp, we select nibble boundaries for the four stepper motor outputs. With the Propeller, those boundaries don't exist and we can use any four contiguous pins to control the motor (we'll see that in just a second).

Next up are the global variable definitions:

idx	VAR	Byte
stpIdx	VAR	Nib
stpDelay	VAR	Byte

Remember that the BASIC Stamp uses an eight-bit core (PIC or SX), so its native variable type is the Byte. Bits, Nibs, and Words are allowed, but they actually take work on the inside of the Stamp to support them. The Propeller uses a 32-bit core, so its native variable type is the Long. Since the Propeller has 16x the RAM space of the BASIC Stamp, we don't have to be so conservative with variable definitions, in fact, by using Longs, the program is more efficient as that is the native type.

```
VAR

long idx, stpIdx, stpDelay
```

Yes, we could have defined these variables as Bytes or Words (there are no Bit or Nib variables in Spin) but, again, it would not have improved the performance of the program.

The next section in our PBASIC version of the program is a **DATA** table for the stepper motor coil patterns.

Steps	DATA	%0011, %0110, %1100, %1001
-------	------	----------------------------

And in Spin:

```
DAT

Steps      byte      %0011, %0110, %1100, %1001
```

By convention, PBASIC **DATA** tables usually appear near the beginning of the program and Spin **DAT** section(s) appear at the end. This is just convention and the compilers do not care either way. Do note that we define the element size of items in a **DAT** table.

And now we get into the working code:

```
Setup:
  DIRB = %1111
  stpDelay = 15

Main:
  FOR idx = 1 TO StpsPerRev
    GOSUB Step_Fwd
  NEXT
  PAUSE 500
  FOR idx = 1 TO StpsPerRev
    GOSUB Step_Rev
  NEXT
  PAUSE 500
  GOTO Main
```

This is very simple; we start by making the motor control pins outputs, initializing the step timing (the delay, in milliseconds, between step changes), and then the stepper is rotated back and forth. The equivalent code in Spin – with a fun modification – looks like this:

```
PUB main

  dira[M4..EN]~~
  outa[EN]~~

  repeat
    stpDelay := 5
    repeat idx from 1 to STEPS_PER_REV
      stepFwd

    pause(500)

    repeat while (stpDelay < 50)
      repeat idx from 1 to STEPS_PER_REV
        stepRev
      stpDelay := stpDelay * 125 / 100

    pause(500)
```

As with the PBASIC program, our first task is to make the motor control pins outputs. And here's where Spin is very flexible with I/O pins. In the BASIC Stamp, we can work with one pin, four pins, eight pins, or all 16. With the Propeller, we can work with any contiguous group of pins that we choose by using the dot-dot notation. This line, then:

```
dira[M4..EN]~~
```

is equivalent to:

```
dira[4] := 1
dira[3] := 1
dira[2] := 1
dira[1] := 1
dira[0] := 1
```

As you see, we've also used the post set to -1 (double tilde) operator as a shortcut. I find this best when the goal is to make all of the target bits one – it prevents possible errors by miscounting the number of bits in the target group. Do be sure to use two tildes as a single post tilde (~) will clear all target bits to zero.

After making the control pins outputs, we set the enable pin high using the **outa** register. Again, the ~ is used. You see, this operator works no matter how many bits are to be affected, hence it is incredibly useful.

And now we start running the motor. There is no **GOTO** in Spin, so the loop construct we use in the PBASIC version is handled with **repeat**. Look carefully, and you'll see that there is a single **repeat** under which everything else is indented. Remember – with Spin – *formatting counts*. If you're unsure about the levels of indenting in a program, the editor will show you by pressing [Ctrl]+[I] (this toggles the indentation display on/off). And you can adjust the indent level of a group of lines by selecting them and pressing [Tab] (indent in) or [Shift]+[Tab] (indent out).

At the top of the loop we set the initial step delay which serves as a speed control for the stepper – the shorter the delay, the faster the stepper will move. Now don't get crazy and think that you can have nearly no step delay. Stepper motors are mechanical devices and do need a bit of delay between steps. If we start with a step delay that is too short, the motor may not run or will just sit there quivering; not a pretty sight ...

Now we do the first [inner] loop that runs the motor forward one revolution. In PBASIC, **FOR-NEXT** is used; in Spin, we use **repeat from**. As you can see, there is no **NEXT** required because, again, it is indenting that defines the block of code for the loop. The only thing we're doing in the loop is moving the motor one step by calling a subroutine.

```
Step_Fwd:
  stpIdx = stpIdx + 1 // 4
  GOTO Do_Step

Step_Rev:
  stpIdx = stpIdx + 3 //4
  GOTO Do_Step

Do_Step:
  READ (Steps + stpIdx), Phase
  PAUSE stpDelay
  RETURN
```

This, too, is simple code, and designed to absolutely be as small as possible. We don't have to work so hard in Spin, though we do have to create our own **pause** method to duplicate the **PAUSE** instruction of PBASIC.

```
PRI stepFwd

  stpIdx := ++stpIdx // 4
  outa[M4..M1] := Steps[stpIdx]
  pause(stpDelay)

PRI stepRev

  stpIdx := (stpIdx + 3) // 4
  outa[M4..M1] := Steps[stpIdx]
  pause(stpDelay)

PRI pause(ms) | c

  c := cnt
  repeat until (ms-- == 0)
    waitcnt(c += clkfreq / 1000)
```

This should all make perfect sense. Note the use of C-like operators: ++ (*pre increment*) and that our **DAT** table can be accessed like a simple array (hence, no **READ** instruction).

The **pause** method here is quite useful and you'll probably want to have it for other programs. As you can see, this method uses local variables; these come from the stack and are not available to the program outside this method. For **pause** we will pass the number of milliseconds to delay, and we use **waitcnt** method to delay one millisecond within a loop.

This loop may look a bit tricky – unless you have a C or Java programming background – as a lot of work is being

packed into one line of code.

```
repeat until (ms-- == 0)
```

What is important to note here is the position of the decrement (`--`) operator; it comes *after* the variable so the comparison (`ms == 0`) will be done first. If the value of `ms` is greater than zero, it will be decremented and the loop code will run. If we wanted to be very verbose, we could expand the line to this:

```
repeat until (ms == 0)
  ms := ms - 1
```

Let's finish up and move on. If you look at the second half of the Spin version you'll see that we've simply added a speed change between each rotation. When the program runs, the motor will spin one revolution forward, then several revolutions backward, slowing down as it does.

MO' MOTORS, PLEASE ...

This is a lot of fun, but now it's time to move on and take advantage of the Propeller's eight cores — well, for the time being, we're just going to use one more. Our goal, of course, is to drop the stepper control into its own core so that it can run freely in the "background" while our "foreground" program is doing other things. By doing this, our foreground is free and, with up to seven background cogs, we can control a whole lotta motors!

If you're new to the Propeller, please let me suggest that you go back and read the April, May, and June editions of this column, focusing especially on June where the idea of background processing and control is explored.

So we've decided to create a stepper motor object; we need to think about its behaviors. What features (behaviors) do we want in our stepper motor object? The basics, I think, should be something like this:

- Control the L293D enable pin
- Set motor to running or stopped
- Set mode to free running or step mode
- Set direction — forward or reverse
- Set motor speed through step delay
- Set discrete number of steps to run before stopping

That's enough to get us started with a fairly full-featured stepper controller. The object is called `stepper.spin`; go ahead and open it now so you can see how things are constructed.

The two key areas, of course, are the **start** method that is used to launch the control into its own cog, and the **runStepper** method that is, in fact, what does the actual work. To get **runStepper** into its own cog, we will use **cognew**. If a cog was available and the method was launched successfully, **cognew** will return a value greater than zero. Here's the **start** method that includes the launch code for **runStepper**:

```
PUB start(ePin, mnTime) : okay

okay := cogon := (cog := cognew(runStepper(ePin + 1), @stack)) > 0

if okay
  en := ePin
  minStpTm := stepTm := mnTime
  setMode(%0000)
  enable(false)
  stpIdx~
  numSteps~
```

The **start** method expects two parameters: the pin that controls the L293D Enable inputs, and the minimum step timing for the motor being used. This method will return *true* or *false* depending on the result of **cognew**. As you'll see in the demo program, we won't actually do anything unless **start** returns a value of *true*.

When we launch **runStepper** with **cognew**, we have to pass along the pin number of coil #1 for the motor — the others are expected to be contiguous. This is critical. I fought for nearly a day when writing the object because I couldn't get the background code to control the motor, while the foreground would happily do it.

Well, I finally gave in and made a call to Parallax. After going through the code with Chip and trying all sorts of things, he suddenly blurted, "Oh, I see what's wrong!" Here it is ... this is big ... please remember it: Each cog has its own I/O pin definitions and, as **runStepper** runs in its own cog, it has to define any I/O pins that it needs to control. By passing the start of the motor pins group to the method, it can set the pins as outputs and update the motor as required.

Okay, assuming that **runStepper** does get launched, the rest of the start method takes care of initializing variables used by the object. Another important point to remember is that all Spin code lives in the main system RAM so the background method (**runStepper**) has access to the global variables in the stepper object. To control the stepper, then, we will create methods that modify the global variables used by the **runStepper** method. Since **runStepper** is king, let's have a look at it.

```
PRI runStepper(m1) | m4, c

m4 := m1 + 3
dira[m4..m1]~~

timer~
c := cnt
repeat
  waitcnt(c += clkfreq / 1000)
  if (mode & M_ENABLED) and (mode & M_RUN)
    timer := ++timer // stepTm
    if (timer == 0)
      if (mode & M_STEPS)
        if (numSteps- > 0)
          if (mode & M_REV)
            stpIdx := (stpIdx + 3) // 4
            outa[m4..m1] := Steps[stpIdx]
          else
            stpIdx := ++stpIdx // 4
            outa[m4..m1] := Steps[stpIdx]
        else
          if (mode & M_REV)
            stpIdx := (stpIdx + 3) // 4
            outa[m4..m1] := Steps[stpIdx]
          else
            stpIdx := ++stpIdx // 4
            outa[m4..m1] := Steps[stpIdx]
```

At first blush, this may look a bit complicated, but as you dig in you'll see it's a lot of small, logical blocks. What we have here — in about 30 lines of high-level code — is a background stepper motor driver. I just think that is very cool.

The method starts by making the motor control pins outputs; we discussed the reason for doing that here earlier. The rest of the code is contained within a big **repeat** loop that will run until the cog gets unloaded. At the top of the loop is a **waitcnt** that inserts a one millisecond delay, so this means that all the rest of the code in the loop will get processed once per millisecond.

We have four status bits that affect the stepper. The first two that we test for are the L293D enabled bit and the motor running bit. If either of those bits is zero (off), then there is no point in going any further. Let's assume that the L293D is enabled and the motor is set to run.

If we inserted the **pause** method from the simple program in the loop, we would not be able to affect the stepper on-the-fly, so timing is handled with a global variable using the increment and modulus strategy that we've used so many times in the past (in PBASIC and Spin). By making *timer* a global variable, it can be reset with *stepTm* when we want to affect the motor speed, and we will get a near-instant change. If *timer* were a local variable, we would have to wait for the current step timing to complete before the change occurred — this might not be a good thing if we had a very long step time.

Once the step timing expires, we check the current mode: step (the motor runs *numSteps* steps and then stops) or free run (motor spins continuously at current speed). When in step mode, we check to see if there are any steps left and if so, run a step based on the direction bit. When in free-run mode, we simply look at the direction and do a step. The code should look familiar as we simply copied it from the **stepFwd** and **stepRev** methods used in the first program.

You'll notice that there is a bit of redundant code in this method. Again, this method is running in its own cog and has its own I/O definitions. If we attempted to use the **stepFwd** and **stepRev** methods from the first program, we would have two cogs (foreground and background) attempting to control the same set of pins — not a good idea. Ask me how I know this (yes, I tried ...).

Okay, let's let 'er rip. We don't need to go through the entire demo — here's the code that defines the motor and gets it running:

OBJ

```
motor : "stepper"
```

PUB main

```
if motor.start(EN, MIN_STEP_MS)
  motor.enable(true)
  motor.setRun(true)
  motor.stepRun

  repeat idx from 1 to 5
    motor.setSteps(STEPS_PER_REV)
    repeat until (motor.getSteps == 0)
    pause(200)
    motor.setSteps(-STEPS_PER_REV)
    repeat until (motor.getSteps == 0)
    pause(200)

  motor.setStepTmr(500 / STEPS_PER_REV)
  motor.freeRun

  motor.setRun(false)
  motor.setDir(motor#RUN_FWD)
  motor.setRun(true)
  pause(5_000)

  motor.setRun(false)
  motor.setDir(motor#RUN_REV)
  motor.setRun(true)
  pause(5_000)

  motor.setRun(false)
  motor.stop
```

We start by defining a stepper object called *motor* and launching it into its own cog. If that works out, the demo puts the stepper into step mode and spins it back-and-forth five times. Note that when we set the number of steps to a negative value, the motor direction is set to reverse. This strategy should be useful for those doing positioning projects and looking at a change of locations; a positive change moves the motor forward, a negative change moves the motor in reverse.

After the wig-wag loop, the step timing is changed to two revolutions per second — we can do this easily because our step timing is specified in milliseconds. After that, we put the stepper into free run mode, make sure the direction is forward (note the use of the named constant, **RUN_FWD**, from the stepper object), and then let it run for five seconds. After the delay, the motor is stopped, the direction is reversed, and the motor is allowed to run for another five seconds. Finally, the motor is stopped and the object is unloaded.

Well, I think that's about enough fun for this month, don't you? Remember, this stepper object is just a starting point and one could certainly add features to it. Before you do that, though, make sure that you've got a good grasp on how the essential code works; once you do, this program can serve as a template for many other hardware control objects.

Until next time, Happy Spinning! **NV**

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- ✓ Great for air shows
- ✓ Patented circuit and design!

For decades we have been known for our novel and creative product designs. Well, check this one out! An aircraft receiver that receives all nearby traffic without any tuning. It gets better... there is no local oscillator so it doesn't produce, and can't produce, any interference associated with all other receivers with an LO. That means you can use it onboard aircraft as a passive device! And what will you hear? The closest and strongest traffic, mainly, the one you're sitting in! How unique is this? We have a patent on it, and that says it all!

This broadband radio monitors transmissions over the entire aircraft band of 118-136 MHz. The way it works is simple. Strongest man wins! The strongest signal within the pass band of the radio will be heard. And unlike the FM capture effect, multiple aircraft signals will be heard simultaneously with the strongest one the loudest! And that means the aircraft closest to you, and the towers closest to you! All without any tuning or looking up frequencies! So, where would this come in handy?

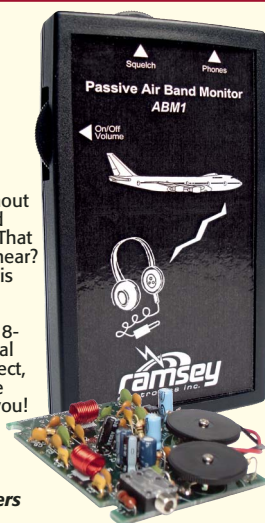
1. At an air show! Just imagine listening to all the traffic as it happens
2. Onboard aircraft to listen to that aircraft and associated control towers
3. Private pilots to monitor ATIS and other field traffic during preflight activities (saves Hobbs time!)
4. Commercial pilots to monitor ATIS and other field traffic as needed at their convenience
5. General aircraft monitoring enthusiasts

Wait, you can't use a radio receiver onboard aircraft because they contain a local oscillator that could generate interfering signals.

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IF Frequencies:	None!
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Audio Output:	700mW, 8-24 ohms
Headphone Jack:	3.5mm stereo phone
External Antenna:	Headphone cord coupled
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Weight:	4 oz. with battery

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Image Rejection:	Greater than -80 dB
Adjacent Ch. Rejection:	Greater than -40dB
Scanner Banks:	4, 20 frequencies each
Audio Output:	1 watt, 8 ohms
Light Controller Output:	3 events, 5 events, 7 events output to controller
Power Requirement:	12VDC, 500mA
External Antenna:	BNC female, rear panel
Dimensions:	5.55"W x 6.45"D x 1.5" H



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WHAT'S UP:

A text-book tour on designing snubbers. I've put this off for a long time because of the math, but the questions kept on a-comin'. So here it is. I also made room for the following:

- ✓ DOS is alive and well.
- ✓ AND logic with diodes.
- ✓ Expanded scale meters.
- ✓ Battery wet/dry quiz.

WITH TJ BYERS

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist.

Feel free to participate with your questions, comments, or suggestions.

You can reach me at: TJBYERS@aol.com

ALL ABOUT SNUBBERS

Q Could you explain the following terms: di/dt and dv/dt ? How should they be taken into consideration when working with both small- and high-power SCRs?

— Z.F.

Q I have seen many circuits in *Nuts & Volts* over the years that use triacs to switch AC loads. Now I want to switch a sump pump on and off using a triac. However, I can't find a simple explanation on when a snubber circuit is required and when it's not. To add to the confusion, I have seen references to new triacs that do not require

snubbers. Know of any guidelines on snubber design and the values of the required components?

— John Cox
Nova Scotia, Canada

A I've put off this discussion for about two years now because of the math, where I have to distill calculus and imaginary numbers into everyday numbers for the hobbyist. The following equations are sometimes approximations, but close enough that they fall within the realm of everyday life. For the first part of the discussion, I will focus on the SCR, simply because the artwork is easier to draw, but what is said applies to both the SCR and triac.

Let's begin with di/dt — the rise in current through the SCR or triac in relationship to time. This is the amount of current (di) that the SCR experiences immediately

Switching

FIGURE 1

Parameter	10RIA	Units	Conditions
di/dt Max. rate of rise of turned-on current $V_{DRM} \leq 600V$ $V_{DRM} \leq 800V$ $V_{DRM} \leq 1000V$ $V_{DRM} \leq 1600V$	200 180 160 150	A/ μs	$T_J = T_J \text{ max.}, V_{DM} = \text{rated } V_{DRM}$ Gate pulse = 20V, 15 Ω , $t_p = 6\mu s$, $t_r = 0.1\mu s \text{ max.}$ $I_{TM} = (2 \times \text{rated } di/dt) A$
t_{gt} Typical turn-on time	0.9	μs	$T_J = 25^\circ C$, at = rated V_{DRM}/V_{RRM} , $T_J = 125^\circ C$
t_{rr} Typical reverse recovery time	4		$T_J = T_J \text{ max.},$ $I_{TM} = I_{T(AV)}, t_p > 200\mu s$, $di/dt = -10A/\mu s$
t_q Typical turn-off time	110		$T_J = T_J \text{ max.}, I_{TM} = I_{T(AV)}, t_p > 200\mu s$, $V_R = 100V$, $di/dt = -10A/\mu s$, $dv/dt = 20V/\mu s$ linear to 67% V_{DRM} , gate bias 0V-100W

(*) $t_q = 10\mu s$ up to 600V, $t_q = 30\mu s$ up to 1600V available on special request.

Blocking

Parameter	10RIA	Units	Conditions
dv/dt Max. critical rate of rise of off-state voltage	100 300 (*)	V/ μs	$T_J = T_J \text{ max. linear to } 100\% \text{ rated } V_{DRM}$ $T_J = T_J \text{ max. linear to } 67\% \text{ rated } V_{DRM}$

(**) Available with: $dv/dt = 1000V/\mu s$, to complete code add S90 i.e., 10RIA120S90.

after turning on. The inrush current is determined by the load resistance and normally applies to resistive loads, such as lamps. If the di/dt current exceeds the di/dt listed on the datasheet, kiss your melted SCR good-bye.

For example, let's take International Rectifier's 10RIA20, which is rated 10 amps at 200 volts. The 10RIA20 datasheet (Figure 1) lists di/dt as 200A/μs. That is, the maximum load at start-up is 200 amps. Theoretically, the 10RIA20 should be able to switch a 1,200-watt halogen lamp at 120 VAC — until you do the math. (If the datasheet doesn't list di/dt, it is approximately equal to the non-repetitive surge current, I_{TSM}.)

Typically, the inrush current of a tungsten lamp is 20 times the operating current. If the current of the lamp is 12 ohms during operation, then its cold resistance is about 0.6 ohms — enough current to exceed the di/dt of the SCR.

The cure is to insert an inductor in series with the load, as shown in Figure 2. The size of the inductor is calculated by $L = V_{PEAK} / di/dt$. Plugging the numbers into the example above, we get $L = 169 / 200 \times 10^6 = 0.8 \mu H$. Don't want to use an inductor? Then the math tells us that the lamp should be limited to 900 watts. If the load is inductive — like a motor — you can ignore di/dt.

Inside the SCR are three parasitic capacitors — one of which is connected between the anode and the gate (Figure 3). And like all caps, it

conducts current until it's fully charged. When power is first applied — like closing a switch or breaker — current rushes in to charge this cap. If the current through this cap exceeds the trigger current of the SCR's gate, the SCR turns on. The critical rate of applied voltage is defined as dv/dt — the rise in voltage across the SCR in relationship to time. Here's where the snubber comes in.

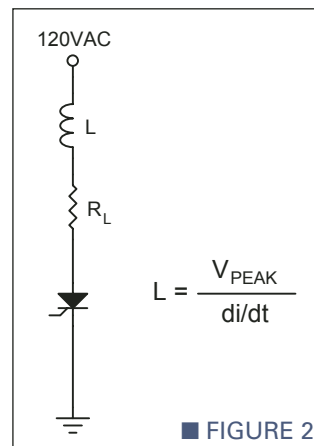
A snubber can be as simple as a parallel capacitor or as complex as an RC network (Figure 4). In circuit (a), a capacitor — several times the value of the phantom capacitor — bypasses the surge current. Its value is calculated by $C = V_{DRM} / (R_L \times dv/dt)$. For the 10RIA20:

$$V_{DRM} = 200 \text{ volts}$$

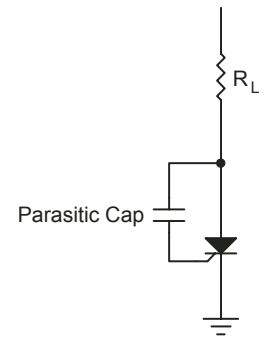
$$I_{TSM} = 200 \text{ amps}$$

$$dv/dt = 100 \text{ V}/\mu s$$

Let's assume R_L equals 24 ohms —

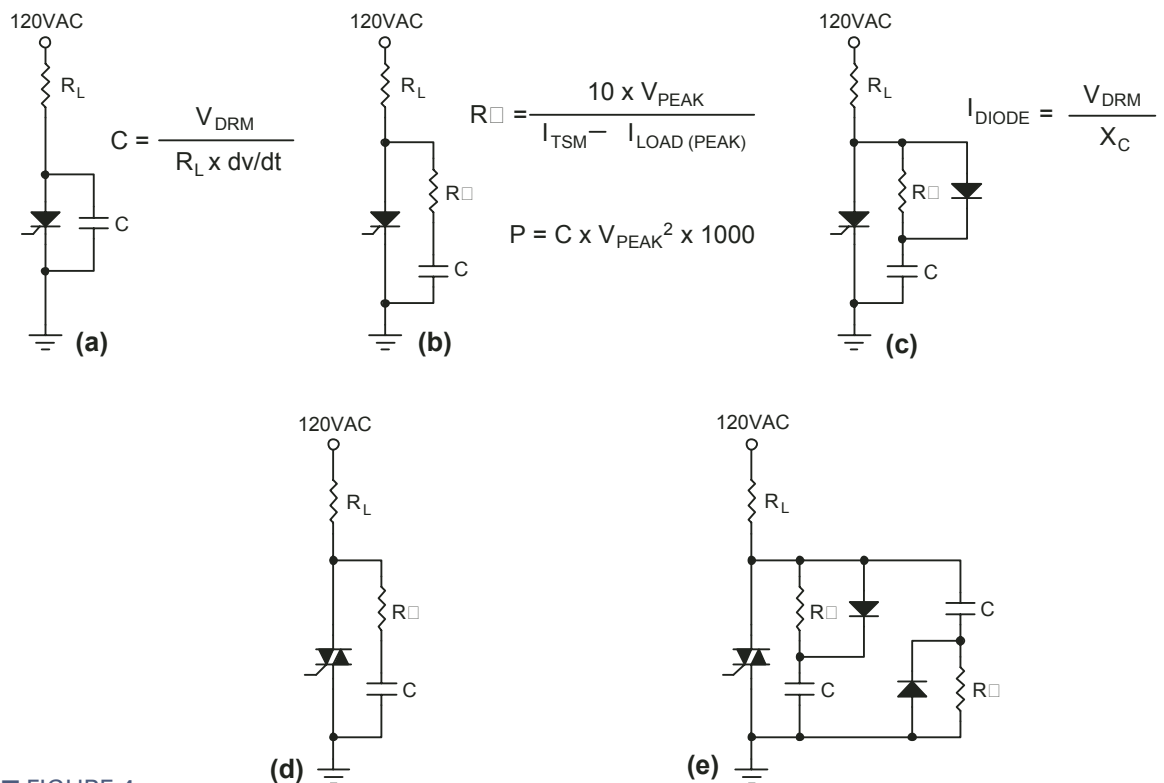


■ FIGURE 3



5 amps at 120 VAC. Plugging the values in, we get $C = 200 / (24 \times 100 \times 10^6) = .083 \mu F$. I'd use a 0.1 μF, 200 volt cap.

Once the SCR turns on, though, the charge stored in the capacitor is forced to discharge through the SCR — a discharge current that can exceed di/dt. To prevent this from happening, a small series resistor is inserted (b). The value of this resistor equals $R_s = 10 V_{PEAK} / (I_{TSM} - I_{LOAD (peak)})$. For a 120 VAC circuit, this becomes $R_s = 10 \times 169 / (200 - 7) = 8.8 \text{ ohms}$. I'd use 10 ohms. The amount of peak current flowing





Diode AND Gate

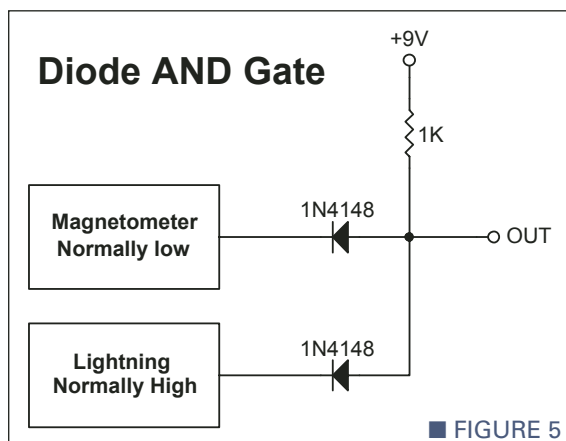


FIGURE 5

through the RC snubber is $I = V_{PEAK} / R = 169 / 10 = 16.9$ amps — well within the di/dt limit of 200 amps. The wattage of R_s is calculated using $P = C \times V_{PEAK}^2 \times 1000 = 0.1 \times 10^{-6} \times 169^2 \times 10^3 = 2.9$ watts.

For this snubber to work, R_s must be smaller than R_L . Otherwise the snubber capacitor will have little effect on suppressing the dv/dt spike. A way around this is to use the circuit in (c), where a diode is added to bypass the charging current around R_s . This way, R_s limits current only when C discharges. As an added benefit, the wattage of R_s is halved to 1.5 watts. The peak diode current is $I_{DIODE} = V_{DRM} / X_c$, where X_c is the capacitive reactance of C at (typically) 1 kHz. Plugging in the values, we get: $I_{DIODE} = 200 / 1592 = 0.13A$. I'd use a 1N4003.

Want to use a triac instead? If $R_s < R_{LOAD}$, then use the snubber in circuit (d). Otherwise, use circuit (e). As to the new non-snubber triacs ... let me see if I can explain. What the semiconductor engineers have done is change the geometry of the triac so that the size of the junction is smaller, which means less parasitic capacitance and less dv/dt impact. In fact, STmicroelectronics claims a 3x improvement with their snubless triacs over

conventional triacs.

Does this mean you can build triac switchers without worry of adding a snubber? Not exactly. Repetitive overvoltage V_{DMR} conditions — like the kind found in switching DC/DC converters — will cause false triggering and possible massive destruction in an improperly compensated design. Higher switching frequencies, too, add to the dv/dt problem. So are

snubbers obsolete? Not today.

DIODE AND LOGIC

I have a magnetometer driveway detector. When it senses a vehicle, I route a nine-volt signal to an interface box that's watched by a recycled PC, which randomly plays WAV files that say "We are being invaded" or something similar. My problem is that weather-lightning drives the driveway detector crazy. I want the PC to check a lightning detector and not play the message if lightning is found. I have an MML101 lightning detector that sounds a buzzer for one second from a nine-volt battery when a strike occurs. How can I put the two together so that when the two events coincide, the PC won't play the message?

— Harvey Lewis Greenwood, AR

What you need is an AND logic circuit. Not the kind built with 40xx or 75LSxx chips, but with two diodes and one resistor (Figure 5). Your magnetometer is a logic low at rest, and a logic high when it detects a car or lightning strike. The MML101, on the other hand, is logic high until a lightning strike happens. Rather than trying to explain this in words, look at Table 1. The way an AND gate works is that if either of the voltage sources are low, the voltage to the

Lightning	Logic	Magnetometer	Logic	Output
N	H	Y	H	H
Y	L	Y	H	L
N	H	N	L	L

TABLE 1. AND Logic Table.

PC is about 0.7 volts. When both go high — the coincidence of no lightning and the presence of a car — the output goes high and sets off your PC's WAV file.

THE COLOR WHITE

I have two things I wish to power. First, a RadioShack Microanta 63-641 flux gate compass. I removed the plug a long time ago and now want to connect it to another car. The power cable has one black wire and another with a white stripe. I also have a couple of Toshiba T2200Sx laptop computers without power supplies. The laptops require 18 VDC, which should be easy to do. However, I don't know which pins on the connectors are which and where to find a compatible connector.

— Bryan McPhee

About the RadioShack compass. Convention has it that the solid color (be it black, red, or yellow) is hot and the striped white or solid white is negative or neutral. As for the Toshiba notebooks, they can't run from an 18-volt wall-wart. The missing 18-volt power pack is, in actuality, a battery charger. It is very specialized to meet the requirements of the batteries inside the notebook for a quick recharge. Try looking on eBay.com for a suitable replacement. You only need one charger for both notebooks — provided they still have a viable battery pack. Don't ever use a notebook without a battery pack — even if it plugs into the cigarette lighter. Doing so will fry the PC. Cards and emails on this subject, okay!

MAKING THE CONNECTION

Can you suggest two simple circuits for the following purposes?

1. To connect my MP3 player (match box type) with the earphone output jack to my sound system with

PHONO, AUX, and CD input jacks.

2. To split my old DVD player with RCA composite video output to two TV sets in separate rooms also with composite input only – without losing signal strength and quality.

— F Wan
Ontario

A The MP3 player can be matched to your AUX input jacks using the RadioShack 15-2451 Mini-to-RCA adapter. (You can find the same adapter cheaper at Jameco, but only if you have more parts to offset the shipping and handling fees.) You will have to adjust the volume control on the MP3 for the best level without distortion.

To split your DVD output, you need a Y adapter – something like the RadioShack 274-881. As for losing signal strength, your VCR should drive both TVs with plenty of signal. Unless the connecting cables are very long. The longer the extension cord, the more signal lost. If that happens, the solution is still simple – just a lot more expensive because it involves a distribution amplifier.

EXPANDED SCALE

Q I am building a weather station that monitors temperature, humidity, barometric pressure, and rain. I want to use the ADC in an AVR microcontroller (which has an input of zero to five volts) to measure the pressure from a Motorola MPX4115A pressure sensor. The sensor outputs about 0.4 to 4.8 volts for a range of 2.17 to 16.6 psi. However, barometric pressure is only from 13.75 to 15.72 psi. This doesn't give me very good resolution. Could you find a circuit using an op-amp that offsets the sensor output and then amplifies it so I can use the full range of the ADC? I've tried a few circuits, but I can't get anything to work.

— Anonymous

A This can be done using a differential amplifier, as shown in Figure 6. The offset voltage is input to the inverting input

of the differential op-amp. This establishes a base level for the amp's output. Using the chart provided in the MPX4115A datasheet, it shows that the range of atmospheric pressures outputs a voltage between 4.0 and 4.5 volts: 4.0 volts equals 28 inches of mercury and 4.5 volts equals 32 inches of mercury. By inputting 4.0 volts to the inverting input, any voltage below 4.0 volts registers as

zero volts out. As the input voltage from the MPX4115A pressure sensor exceeds 4.0 volts, the output voltage of the differential amp increases in step.

Unfortunately, they are baby steps – not nearly big enough to cover your ADC's five-volt span. No problem, we simply amplify the signal by 10X using a non-inverting op-amp. Why didn't I have the differential amp also multiply the

signal by 10? First and foremost, it's more complicated than using a single feedback resistor (27K) of the non-inverting op-amp to fine-tune the exact gain needed. Second, it frees the differential amp to do what it does best without introducing non-linear distortion.

This interface isn't limited to the Motorola pressure sensor. It can be used in any application where you

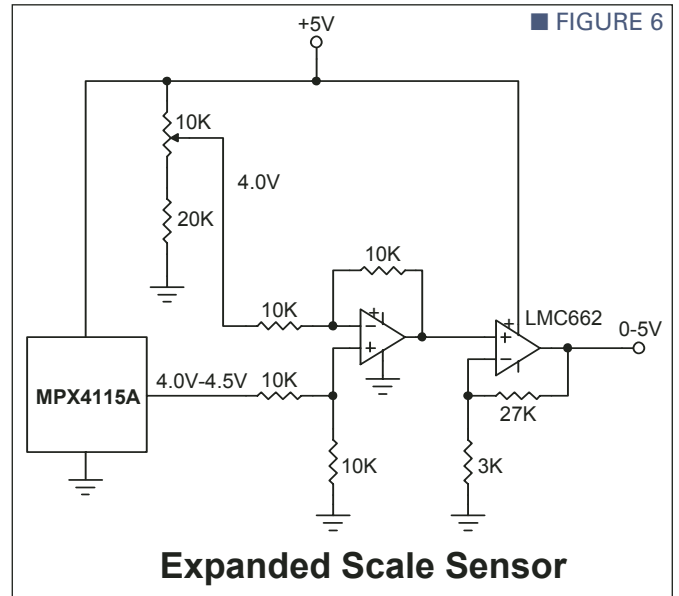


FIGURE 6

Expanded Scale Sensor

MAILBAG

Dear TJ,

Regarding your circuit in Figure 11 ("High-Side Switch") in the May '06 issue, I think a TIP32 will work a lot better (the TIP31 is an NPN). Also, I'm not sure the circuit will be good for up to three amps, unless the 4N25 has a really huge current transfer ratio, and the 1K resistor is reduced in value (maybe to zero?). A useful place for a resistor would be across the TIP32 base to emitter, for better turn-off.

— JW

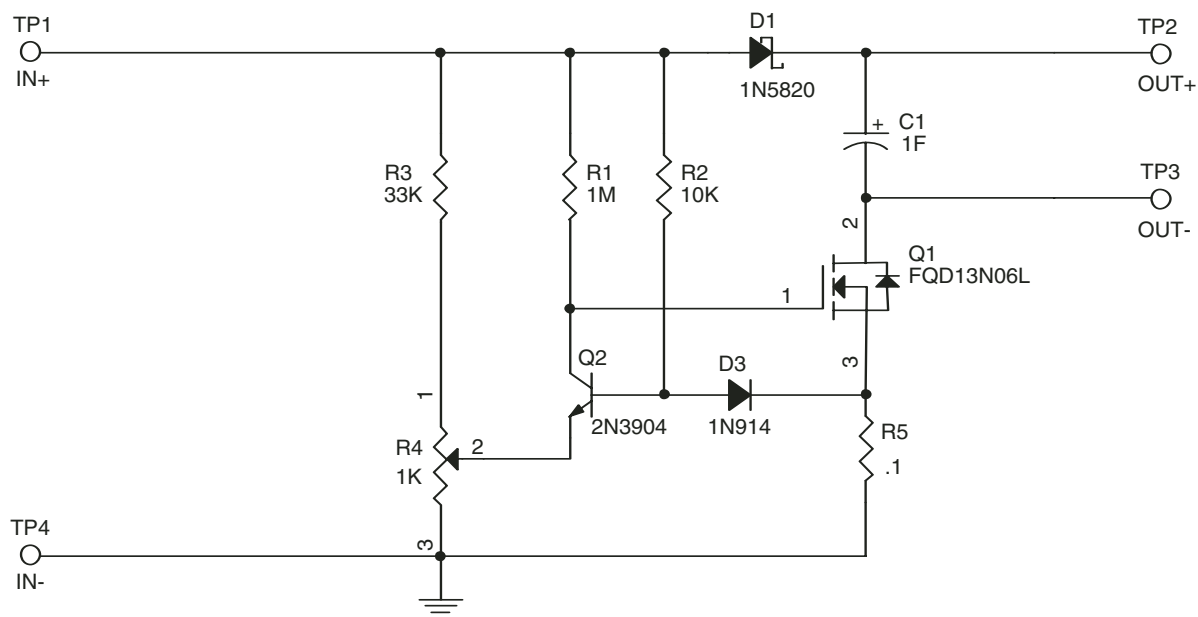
Dear TJ,

I just read the May '06 issue about high-side switching and it filled a gap in my knowledge base. I had been using low-side switching in a circuit and decided to build Figure 11 to see if high-side

switching would work better in my design. You list TIP31 as a PNP transistor, but it is an NPN. Did you mean to use TIP32 in the circuit? Would a 6N138 or 4N33 optical isolator work, as well?

— Robert B. Lang Jr.

Response: Oh, oh. It's a typo on my part – should be TIP125. About the 4N25 optoisolator I recommended, a few years ago the transfer ratio was 20% – today it's typically 100%. So the calculations are for a saturated 4N25 transistor with a TIP125 gain of about 1000. However, any 4Nxx or 6Nxxx optoisolator – some of which are Darlington's with a transfer ratio of 500% and more – will work. Lots of variables here, depending on what you have in your junk box, its vendor, and vintage. Thanks for the catch! – TJ



NOTES

1. Q1 Controls current flowing through R5 and thus, C1 while charging. Use N-channel logic level (V_{gs} on $\leq 3V$) device.
2. Q2 is error amp, controlling gate voltage on Q1. D3 compensates for B-E voltage drop on Q2. R1 determines gain of error amp, R2 provides bias current for D3.
3. Voltage at Q1 source should be maintained close to voltage set by R4. Thus, R4 sets the current limiting level.

■ FIGURE 7

want to monitor a narrow range of a greater voltage input — an expanded scale voltmeter, for example, that would monitor a 12-volt gel-cell between 11.0 and 13.2 volts to determine percentage of charge.

BATTERY QUIZ

Q Batteries are divided into two types: dry and wet. For sealed and non-sealed lead-acid batteries, are both

considered wet?

— N.S.

A In a manner of speaking, all lead-acid batteries are wet. As to how wet is a matter of definition. Most unsealed lead-acid batteries — like those under the hood of your car — are categorized as flooded. That means they have water as their base with a hint of sulfuric acid. If they are tipped sideways, they spill out corrosive liquid water (the newer cap-less batteries to a lesser extent — but still). Gel-cells use a thixotropic gelled electrolyte that behaves more like Silly Putty than water (think the Steve McQueen movie *The Blob*). Therefore, it can be operated in virtually any position — although upside-down is not recommended. The “liquid” is trapped in the cell by special pressurized sealing vents. The sealing vent is critical to the performance of the gel-cell. The cell must maintain a positive internal pressure. If opened, the cell will quickly evaporate and not perform.

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What constitutes a dry cell? A carbon-zinc cell, alkaline "Bunny" battery, lithium watch cell, among others. Anything without a liquid or gel electrolyte. While most dry cells are primary — that is, they can't be recharged — the ability to recharge doesn't draw the line between wet and dry because today's new crop of dry-cell Li-Ion batteries are rechargeable. Dry cell leakage? A topic for another day.

READER'S CIRCUIT

I just received my copy of the April '06 issue and saw your suggestion of connecting a supercap across the five-volt supply lines on the USB as a solution for providing energy storage for a hard drive. Although this energy storage circuit may work well, the USB specification sets a stringent limit on transient current draw. An uncharged 1F cap would look like a short circuit to your hub, and the PC would most likely shut the port down as soon as it's plugged in — as it will do on my computer.

I have developed several USB peripherals, and this issue has come up before. To prevent port shutdown, I developed the circuit shown in Figure 7. Q1 controls the charging current for C1 and, thus, its rate of charge. Q2 — in combination with D3, R1, and R2 — forms an error amplifier. The voltage drop across D3 nulls the base-emitter voltage drop on Q2 (about 0.6V). This circuit forms a closed loop so that the voltage drop across R5 will be approximately equal to the voltage set by R4 while the capacitor is charging. The higher the voltage setting on R4, the higher the current, and the faster the rate of charge. When the capacitor is charged, it will cease drawing any current. Q2 will turn off, R1 will pull the gate of Q1 to the supply rail, which will turn it fully on.

— Stephen Santarelli

COOL WEBSITES

The old proverb says "Seek, and ye shall find," and that's certainly true of free software. The Internet is chock full of freebies: free software for e-commerce, auctions, business management, and more.

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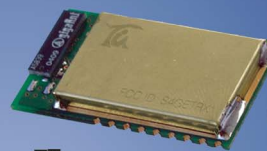
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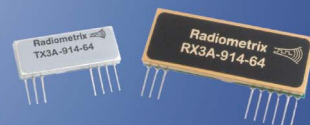
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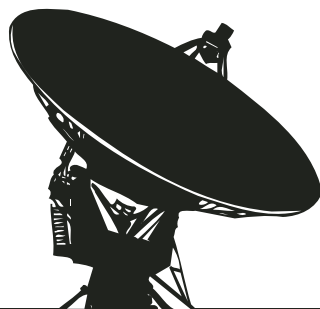
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ES-U-1001-R SERIES USB RS232 SERIAL ADAPTER

EasySync Ltd. announces the ES-U-1001-R series USB to RS232 Serial Cable Adapters. This new design sets the standard in appearance and functionality with its high gloss white enclosure and side-lit blue traffic indicators designed to appeal to discerning PC and MAC users alike. For additional connection reliability, both the USB and nine-pin D-sub serial connectors are gold plated.

Based on the very latest FTDI "R" series chip set technology, the ES-U-1001-R offers outstanding performance and quality at a remarkable price. The ES-U-1001-R is supplied in full retail packaging including software CD with WHQL-signed communication port drivers.

MAC users will be pleased to note that the ES-U-1001-R supports the new OS X Intel based platforms, as well as the traditional Power PC based models.

The ES-U-1001-R is immediately available in two lengths. The 10 cm version (ES-U-1001-R10, \$22.50 each) is perfect for the laptop bag, while the 1 m version (ES-U-1001-R100 \$24.98 each) provides a nice length for most other applications.

For the budget conscious, a 10 cm version without traffic indicators and downloaded device drivers is also available (ES-U-1001-B10, \$18.48 each).

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THE NEW ITROL-MC2

Small system closed loop control has always been a cost sensitive issue that often requires trade-offs in performance and maintenance. The new itrol-MC2 specific purpose controller and monitor can eliminate this dilemma. It can bring a closed loop control function to any motor driven machinery, while providing a remote control function using an Ethernet network or Internet connection.

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Typical applications include water pump systems like municipal swimming pools, wells, and circulation installations for livestock feeders, aquariums, irrigation, or sump pump systems, remote lift stations, remote cooling fans, refrigeration systems, even conveyor systems.

The itrol-MC2 features include:

- No programming required — simple set-up process using a browser on Windows or Mac.



- Remotely control a motor or other loads over an Ethernet network or the Internet.

- Closed loop verification of motor operation and condition with built-in 0-60.0 amp AC ammeter and 0-1,5,10 VDC analog sensor input.

- External contact or 0-5 VDC digital input for local control of motor with selectable contact form and operation.

- Multiple 24 hour timers for time cycled motor control.

- Ammeter and analog sensors have min/max displays for pinpointing trends.

- User ID and password access control.

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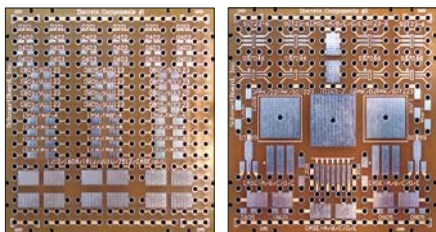
- All operational data is stored in log files and can be imported into various data base programs.

- Three models with varying I/O, starting at \$290.00.

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"ez" BOARDS FOR DISCRETE COMPONENTS

SchmartBoard, the developer of a new technology that has simplified the creation of electronic circuits for hobbyists, students, and electronic



engineers, has released two new boards that address tiny discrete surface mount components.

The first new board (EZ Discrete #1) supports 0201, 0603, 0805, 1206, 1210, 1608, 1812, 2010, 2512, and CAES-A, B, and C. The second new board (EZ Discrete #2) supports SOT23-3, 5, 6, SC70-5,6, DPAK, D2PAK, SOT223, TO263-7, SOT89, 0805, 1206, and CASE-A, B, C, D and E. Many of these components are very small and require a magnifying glass to see. Schmartboards lock the component in place on the board, and are hand-soldered by simply touching the board with the soldering iron next to the component. Because the solder is already on the board, the job is much simpler.

Before the SchmartBoard|ez line of prototyping boards was launched in September 2005 at the DEMO fall show, it required an expert to hand solder most surface mount components. SchmartBoard's technology has now made it possible for novices to hand solder some of the most difficult components quickly and flawlessly the first time they pick up a soldering iron. The SchmartBoard|ez family of boards allow engineers, students, and hobbyists to hand solder surface mount components and expanded their capabilities in creating electronic circuit projects.

For more information, contact:
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SINGLE CYCLE CORE 8051 MICROCONTROLLERS

Atmel® Corporation has announced the introduction of four new 14-pin and two new 16-pin



microcontrollers based on the Atmel 8051 single cycle core.

Atmel's single cycle core architecture executes each byte fetch in a single clock cycle resulting in 70% of all instructions being executed in a single clock cycle. Compared to the traditional 8051 devices, this can either increase performance up to 12 times or reduce power consumption by up to 80%.

Low pin-count microcontrollers have emerged as a fundamental building block of many general-purpose applications. The AT89LP213/413, AT89LP214/414, and AT89LP216/416 devices are cost-effective eight-bit microcontrollers

ideal for applications requiring not only low-pin count, but low power and high performance in a small footprint. These new microcontrollers reduce system cost with a variety of on-chip features, enabling faster time-to-market for products such as white goods, remote controls, smart sensors, and disposable electronic products.

The AT89LP214 and AT89LP213 have 2 Kbytes of In-system Programmable Flash whereas the AT89LP414 and AT89LP413 have 4 Kbytes of Flash. The 16-pin versions are the AT89LP216 and AT89LP416 that have 2 and 4 Kbytes of Flash memory, respectively. These devices come with a rich feature set which includes on-chip debug, on-chip hardware multiplier, Pulse Width Modulation, analog comparator, internal RC oscillator, and 12 general-purpose I/Os for application use. They are ideal for motor control, battery management, and other general-purpose applications.

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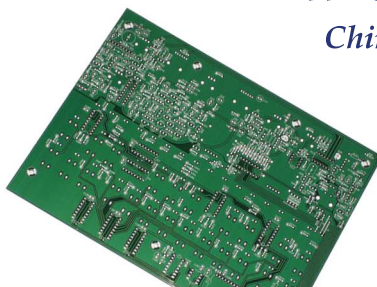
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The AT89LP214 and AT89LP213 are available in 14-pin TSSOP and PDIP packages while the AT89LP216 is available in 16-pin TSSOP, SOIC, and PDIP packages. The 10K unit

price is \$0.87 for AT89LP214 and AT89LP213, and \$0.91 for AT89LP216. Samples for AT89LP414, AT89LP413, and AT89LP416 will be available in 4Q 2006.

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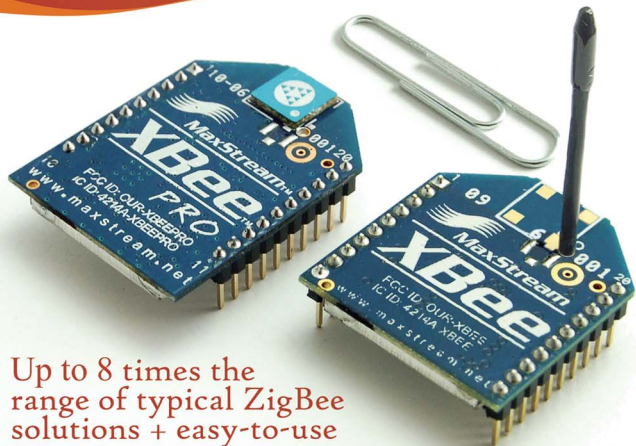
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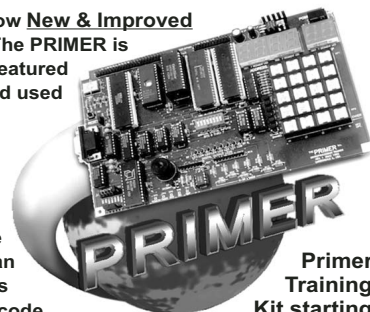
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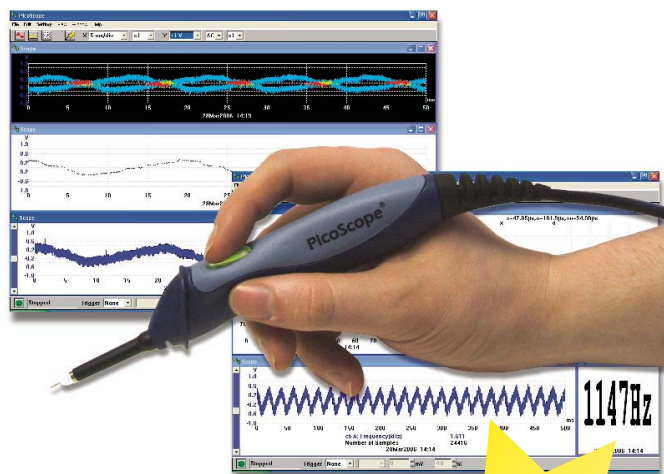
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■ THIS MONTH'S PROJECTS

Microphone Amplifier	36
Don't Blow a Fuse!	40
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■ LEVEL RATING SYSTEM

To find out the level of difficulty for each of these projects, turn to our ratings for the answers.

- Beginner Level
- Intermediate Level
- Advanced Level
- Professional Level

As many of us have discovered the hard way, the output of a good microphone is weaker than any other kind of audio signal.

If you want to use your stereo amplifier as a PA system, or view your speech on an oscilloscope, or use a high-quality dynamic mic with your computer's sound card, you need more amplification.

A QUICK HUNDRED SIMPLE 100x MICROPHONE AMPLIFIER

I built this simple amplifier so that a friend could record music with his Creative Labs "Nomad" digital audio recorder, which only has line-level inputs. The amplifier is a handy audio problem-solver and gives excellent, high-fidelity sound.

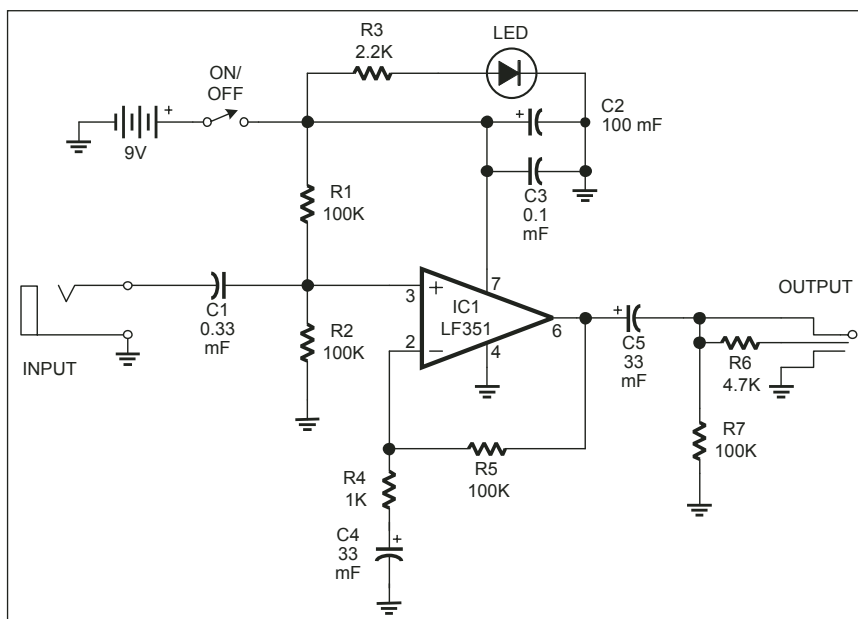
How it Works

A microphone generates elec-

tricity from sound; its output is about 1 millivolt RMS. Line-level audio — the kind of signal that goes from a tuner or CD player into an amplifier — is about 100 millivolts RMS. Clearly, to turn a microphone signal into a line-level signal, you need to amplify it by a factor of 100.

That's what this circuit does (Figure 1). It's built around an

■ FIGURE 1. A single op-amp gives a gain of 100 to turn microphone-level into line-level audio.



LF351, TL071, or TL082 wideband low-noise operational amplifier. Although you can use the more common 741 op-amp for testing, you won't get very good sound; the 741's noise level is too high and its frequency response is too limited. In fact, this amplifier is a great way to learn about the audio performance of different op-amps. Most single eight-pin op-amps — including all the types I've mentioned — have the same pin connections, and you can swap them in the same socket.

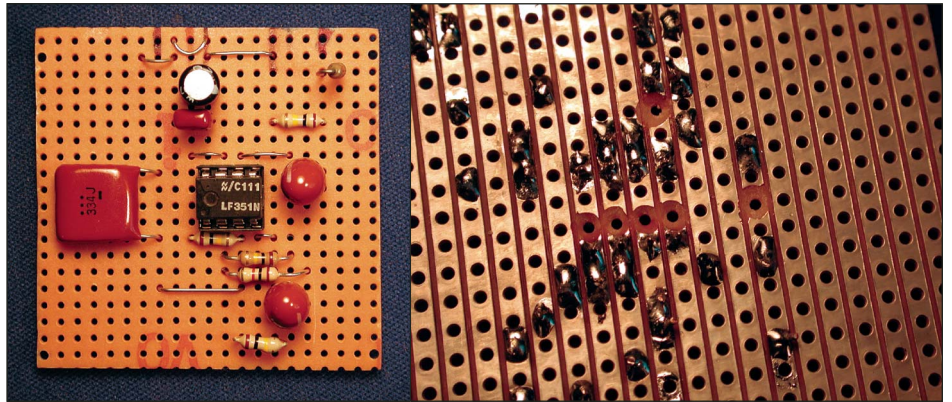
The gain of 100 is set by resistors R5 and R4 in the negative feedback loop. What this means is that we are feeding 1/100 of the output signal back into the inverting (minus) input. The op-amp tries to keep the two inputs at the same voltage, and in order for it to do this, the output has to swing 100 times as much as the positive (plus) input. Magic!

In theory, there is no distortion at all from an amplifier controlled this way, because the gain is controlled entirely by resistors, which can't distort. In practice, the total harmonic distortion (THD) of this amplifier is well under 1%, probably well under 0.3%.

Purists will note that we are actually feeding back 1/101 of the input signal; that is, $1K / (1K + 100K)$. I said 1/100 because the resistor values aren't that precise. If you need less gain, reduce R5. For example, if you change R5 to 22K, the feedback becomes $1K / (1K + 22K) = 1/23$ and the gain becomes 23.

The input jack is whatever suits the microphone; I used a miniature phone jack. The output is designed to plug into a stereo or mono line-level input or even a sound card microphone jack, and that's the reason for resistor R6, connected to the middle conductor (the ring) on a three-conductor miniature phone plug.

In a mono jack, this conductor is grounded; in a stereo jack, it's the



■ FIGURE 2. Circuit is built on stripboard, which has copper conductors spaced like IC pins. To break a conductor, twirl a drill bit in it momentarily by hand.

right channel; and on a computer sound card, it supplies power for the one-transistor amplifier that is built into sound card microphones. R6 ensures that no matter which of these things is present, the amplifier will work perfectly. When feeding a stereo input, the signal will be slightly weaker

in one channel than the other, but you can correct this with the balance control.

Coupling capacitors C1, C4, and C5 are large enough to give flat frequency response from at least 20 to 20,000 Hz. Resistor R7 keeps C5

PARTS LIST

RESISTORS (All 1/8 watt or greater)

- R1, R2, R5, R7 – 100K
- R3 – 2.2K
- R4 – 1K
- R6 – 4.7K

CAPACITORS (All rated at least 12 volts)

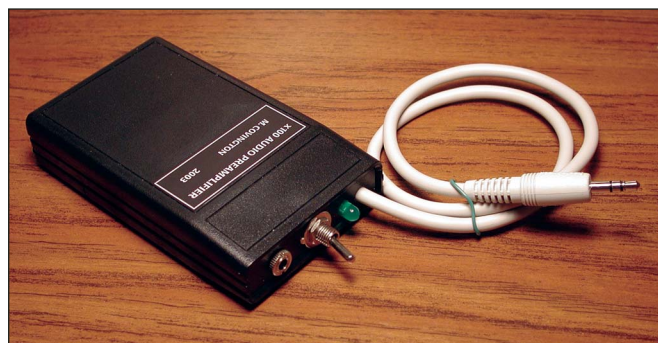
- C1 – 0.33 microfarad, polyester, or Mylar
- C2 – 100 microfarads, electrolytic, 35 V
- C3 – 0.1 microfarad, polyester, Mylar, or ceramic disc
- C4, C5 – 33 microfarads, 35 V, high-grade tantalum

SEMICONDUCTORS

- IC1 – Operational amplifier, LF351, TL071, TL081, or equivalent. Do not use 741.
- LED – Light-emitting diode, red, yellow, or green, preferably high-brightness type.

MISCELLANEOUS

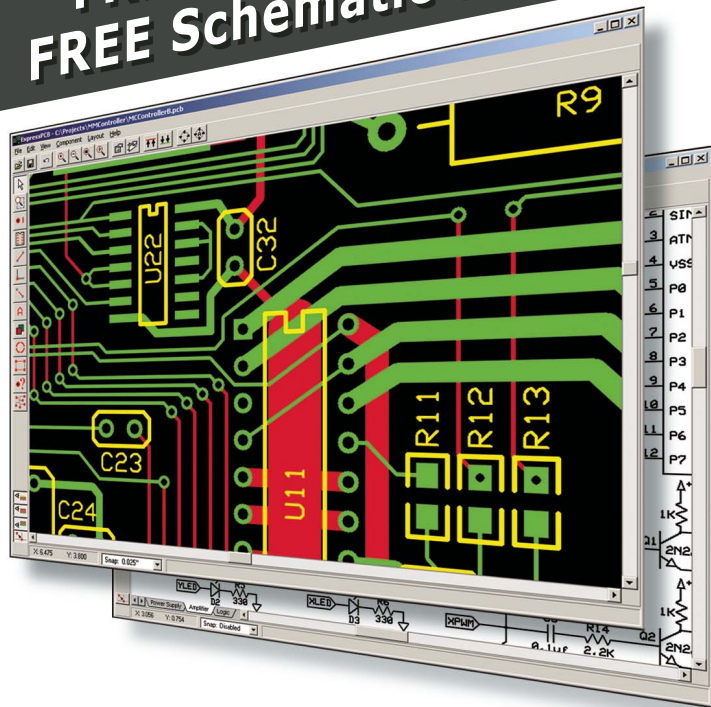
- Nine-volt battery
- Battery connector
- Miniature SPST switch
- Enclosure
- Circuit board (author used stripboard, available as item ECS-4 from All Electronics, www.allelectronics.com)
- Input jack suitable for microphone
- Output plug and/or shielded cable (author used cable with three-conductor miniature phone plug, obtained by cutting off a shielded extension cable)



■ **FIGURE 3.** Completed circuit is housed in a Pac-Tec enclosure with battery compartment. Label was designed using Corel Draw and made by laser-printing on Avery weatherproof white plastic label material, available in office supply stores.

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charged with the right polarity, to prevent distortion. (There's an exception: when connected to a computer sound card microphone input, R6 wins out and the capacitor may experience slight reverse voltage. It's better to use the line-level input of the sound card.)

R1 and R2 bias the op-amp for single-supply operation, and C2 and C3 provide power supply filtering so that the AC impedance of the battery doesn't affect the circuit. The power-on LED actually consumes more power than the amplifier itself, but in my situation, it was necessary to keep the switch from being left on; you might want to try a high-brightness LED and see if you still get adequate brightness with R3 increased to 4.7K or 10K.

Construction

Because this is a simple project with relatively few components, I did not design a printed circuit board. Instead, I built the circuit on stripboard (Figure 2), a material widely used in Europe, and available in North America from All Electronics (see the Parts List). Stripboard has holes spaced like IC pins, and each column of holes is joined by a copper track running from one end of the board to the other. To break a track, you twirl a drill bit in a hole by hand. Obviously, you have to make a row of breaks under each IC, but apart from that, surprisingly few breaks are needed. I find I can prototype quickly this way, though the circuits occupy more board space than on other kinds of circuit boards. With this simple circuit, bulk is not a problem.

This is a high-gain amplifier with a high-impedance input, so it's important to separate the input and output. In my prototype, the output went directly into a shielded audio cable. The input was shielded by keeping it well away from the rest of the circuit, and by grounding the stripboard tracks on either side of the input signal. **NV**

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Imagine yourself sitting on the veranda on the Serengeti in Africa. The sun is warm and you can feel the gentle breeze. From a distance, you can hear the elephants trumpeting and the faint sound of zebras running. On the roof there is a group of baboons playing and chattering.

All of a sudden there is the smell of burnt wiring. Your probe just slipped as your mind is not on troubleshooting.

This peaceful scene is interrupted by the sound of your cursing as you have blown your last fuse. The Serengeti is a vast place, filled with many animals and beautiful sites. A great place to see, but a difficult place to troubleshoot electronics.

DON'T BLOW A FUSE!! JUST RELAX!

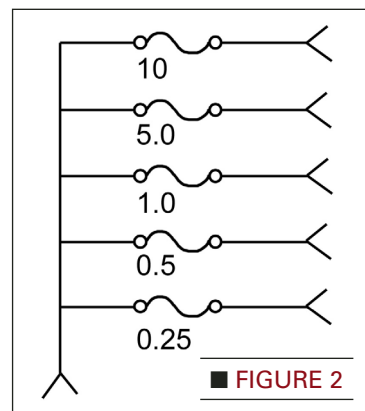
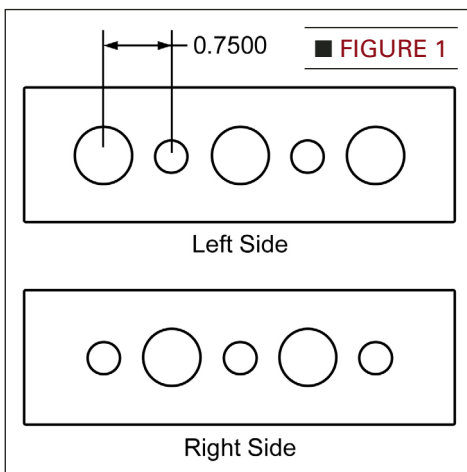
As a retired clinical chemist, bio-engineer with a PhD in experience, one of privileges I have is being sent all over the world with expenses paid. I'm a teaching consultant for both government and non-government organizations, but I often act as a repair technician. (Tough job, but someone has to do it!) If you fix it, you are a hero. If you don't, no one seems to care as no one else has been able to fix it either. It's a win-win situation. And you meet a great number of nice people.

Unfortunately, there are not any parts houses and TV repair places are non-existent in the areas I'm sent. One of the problems of my travels is carrying enough spare parts to complete repairs, especially fuses. They are difficult to obtain if not damn near impossible to find. I normally carry about two to three fuses of each amperage from .1 to 10 amps for both types 5

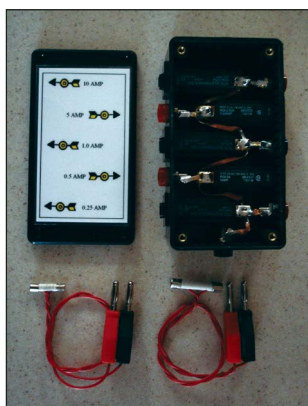
mm and the .25 inch standard fuse.

Many times, a non-working piece of equipment will present itself with a blown fuse. This can be caused by a power surge and the varistor doing its job by blowing out the fuse. However, it is not uncommon for the power supply to be shot also. Ninety percent of the time when I'm troubleshooting, I don't have a schematic and it's often plug and replace what you have in your box and see if the fuse blows again.

Within my bag of tricks — to avoid having to replace fuse after fuse thus depleting my precious supply — I designed a substitution box that uses circuit breakers. This box contains five circuit breakers: 0.25, 0.5, 1, 5, and 10 amps. This seems to cover the most common types. I developed a fuse adapter which substitutes for the fuse. This has saved me a lot of grief and many a fuse. I regularly use it in series with an amp meter to check on power consumption.



I also find it useful when prototyping at home, as I place it in series with the power supply. I'm sure that most of you have placed a part in backwards only to see a puff of smoke coming from your project. Just use this small black box and you have peace of mind. Again, I use it in series with an amp meter.



■ PHOTO 1

Construction

This is one of the simplest projects you can build. I used a 2.4" x 4.4" x 1.4" handy box. The total cost is less than \$35.

On the left side of the box I drilled three .625" holes for circuit breakers with two .323" holes in between for banana jacks. On the right side of the box I drilled three .323 holes for banana jacks with two .625" holes for circuit breakers. The holes are spaced .75" apart. One .323" hole is drilled on one end for another banana jack. This is the common connection (see Figure 1).

Each circuit breaker is wired to the common connection using a heavy buss wire or braided copper shield such as used for solder wick. The banana jack on the opposite side is connected to each different circuit breaker (see Photo 1).

The fuse adapters are made out of fuses with the glass removed. This can be done with a pair of pliers or a vice. Place a piece of tape around the glass

before cracking the glass to prevent the glass from being scattered. Remove the excess glass from the ends of the fuses using a drill bit.

For the .25" x 1.25", I used 3/16" hollow PVC tubing available from most hobby shops. Cut the tubing to one inch and drill two 3/32" holes 1/4" apart from the center of the tubing. Thread two #20 gauge

stranded wires into the holes and through the tubes out the ends. Solder the wires to the inside of the caps. Place some five minute epoxy glue into each end and gently pull the wires so that the PVC fits inside the caps.

For the 5 mm x 20 mm fuses, I used the same 3/16" hollow PVC tubing but turned it on a lathe to 11/64" in diameter. You can use a drill press and sand paper if you don't have a lathe. Cut the tubing to 5/8" and follow the above procedure. Place two banana plugs on each end of the wires coming from the fuse adapters.

To use, remove the bad fuse, snap in the fuse adapter, and plug one end into the common and the other end into the jack of the circuit breaker. By adding a third wire with two banana jacks, you can place an amp meter in series with the fuse adapter.

Happy troubleshooting! As they say in Swahili, tutaonana and asante. **NV**



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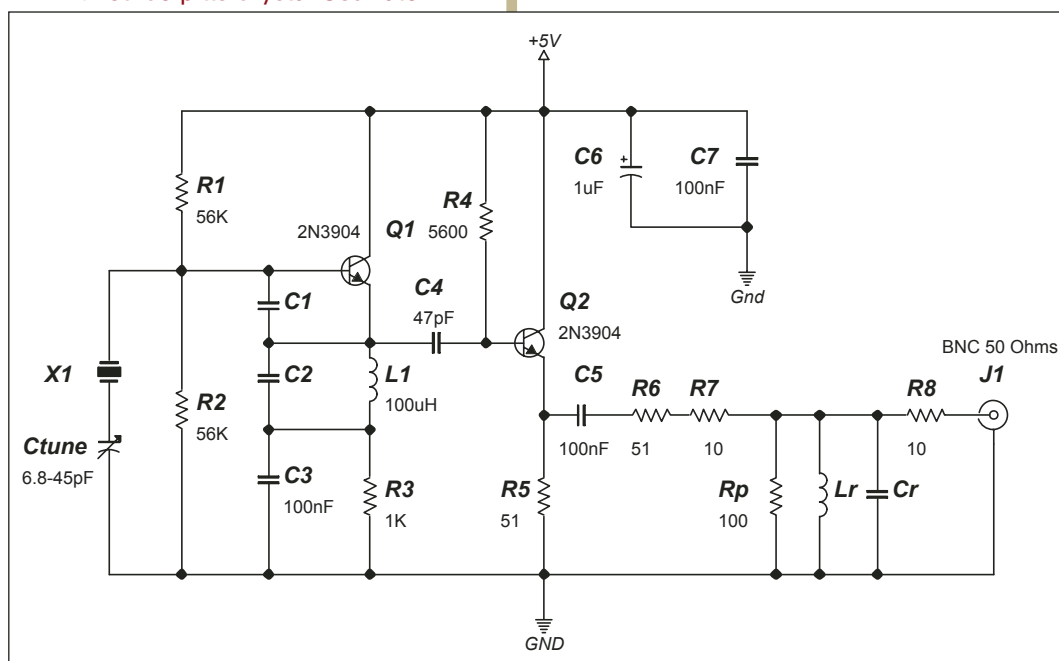
ITEM	DESCRIPTION	QTY.	MOUSER PART NO.	PRICE
<input type="checkbox"/> Box	2.5" x 4.75" x 1.75"	1	546-1591CTBU	\$6.57
<input type="checkbox"/> Banana Jacks		6	530-108-0302-1	\$0.93
<input type="checkbox"/> Banana Plugs		4	174-R822B	\$0.75
<input type="checkbox"/> Circuit Breaker	0.25 amp	1	655-W28XQ1A-0.25	\$4.26
<input type="checkbox"/> Circuit Breaker	0.5 amp	1	655-W28XQ1A-0.50	\$4.26
<input type="checkbox"/> Circuit Breaker	1 amp	1	655-W28XQ1A-1	\$4.21
<input type="checkbox"/> Circuit Breaker	5 amp	1	655-W28XQ1A-5	\$2.38
<input type="checkbox"/> Circuit Breaker	10 amp	1	655-W28XQ1A-10	\$2.30
<input type="checkbox"/> Fuse	5 mm	1		
<input type="checkbox"/> Fuse	.25"	1		
<input type="checkbox"/> PVC	3/16" x 1"	1		
<input type="checkbox"/> PVC	11/64" x 5/8"	1		
<input type="checkbox"/> Wire	12" #20 Stranded	4		



If you would like a circuit that is useful in obtaining a high-accuracy, low distortion RF source capable of driving a 50 ohm load, then you've come to the right place.

The circuit in Figure 1 is the schematic for a common collector series tuned Colpitts crystal oscillator.

■ FIGURE 1. Schematic of a Series Tuned Colpitts Crystal Oscillator.



DESIGN YOUR OWN CRYSTAL OSCILLATOR

Photo 1 shows the oscillator circuit board with an output filter board. It was constructed on a piece of double-sided printed circuit board (PCB) material. The topside of the PCB was etched leaving "islands" on which to solder the components. The copper foil on the reverse side of the PCB is connected to ground and forms a ground plane for the circuit. When constructing this circuit, it is important to keep all of the component leads as short as possible.

What is "Q"

We will be using the term "Q" in the following text, and it is impor-

tant to understand its definition. The Q of a resonant circuit is known as the "Quality" factor. Q determines the sharpness of the frequency response curve at a given resonant frequency. Higher Qs provide greater frequency selectivity. The equation for Q is

$$Q = F_c / (-3 \text{ dB bandwidth})$$

The -3 dB bandwidth is also known as the half-power bandwidth. This can also be re-written as

$$Q = F_c / (F_h - F_l)$$

where F_c is the center (resonant) frequency, F_h is the higher -3 dB frequency, and F_l is the lower -3 dB frequency. These -3 dB points are also known as the cutoff frequencies (f_c). Note that this is a lower case "f." For example, let F_c (center frequency) = 10 MHz, F_h = 10.5 MHz, and F_l = 9.5 MHz. Solving for Q, $Q = 10 / (10.5 - 9.5) = 10$.

This Q should not be confused with component Q which is used to measure the quality of an inductor or capacitor.

Design Info

This circuit uses a series resonant crystal that

is specified for 10 pF to 35 pF loading. The crystal should operate in the fundamental mode. Adjusting C_{tune} will compensate for the loading of capacitors C1 and C2. Furthermore, C_{tune} can be set to make small changes in the oscillator frequency. Q1 and its associated components form a Colpitts crystal oscillator and Q2 is used as a buffer.

The output impedance of Q2 is about 20 ohms. Because there may be distortion present at the output of this buffer, it is followed by a resonant circuit composed of L_r and C_r (see Figure 1). The resonant circuit formed by L_r and C_r requires a source and load resistance of 50 ohms. R7, R8, and R_p form a 4 dB attenuator (more on this later).

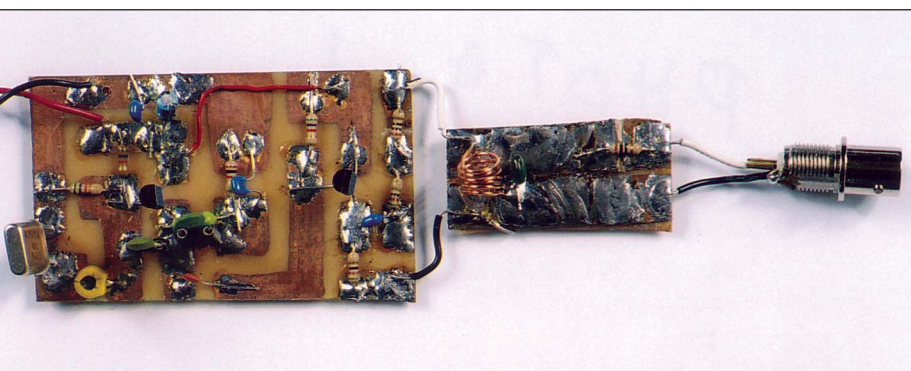
A Design Example

We will now design a 4.19304 MHz crystal oscillator. First, obtain a crystal (X1) of this frequency. Table 1 lists the values for C1 and C2 corresponding to this frequency. For this design, C1 = 220 pF and C2 = 100 pF. Next, we can calculate the values for the resonant circuit at the output of the buffer. The design equations are given in the sidebar Equations 1.

It is necessary to specify the following parameters for the equations: F_c (center frequency), Q (loaded Q), Q_p (Q of the inductor), and R (source and load resistance). Let $F_c = 4.19304$ MHz. Q_p for an airwound coil is approximately 110 and $R = 50$. A good choice of the loaded Q for this resonant circuit is 5.

Higher Qs provide more selectivity, however, at higher frequencies the value of the inductor L_r may be very small. Examine the equations in the sidebar. Solve for X_p (the reactance at resonance) and then solve for L_r and C_r .

For this example, $L_r = 180$ nH and $C_r = 8$ nF. The closest standard value to C_r is 8.2 nF. I used a 2% tolerance part for C_r . L_r is a handwound coil. For information on how to wind this coil,



■ PHOTO 1. Oscillator Board and Filter.

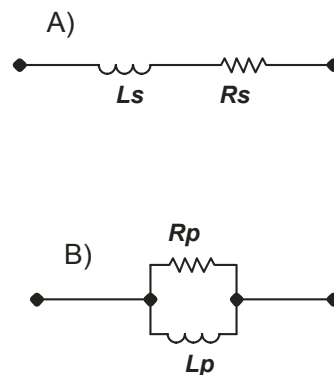
refer to Sources 1 and 2 listed in this article. In some cases, the calculated value of C_r may be between standard values. If this is the case, two capacitors can be used in parallel to achieve a closer match to the calculated value. Again, L_r is 180 nH. This is not a lossless component. The coil has an inductance with a series resistance (see Figure 2A).

There exists a transformation equation that will give us the equivalent parallel resistance (see Figure 2B). The design equations for R_p are given in the Equations 2 sidebar. The inductor is wound from 22 gauge wire. The resistance of this wire is 16.2 ohms per 1,000 feet. The stretched coil length is six inches (.5 feet). R_s is then calculated. Q_p of the air core inductor is 110. We will now calculate R_p from R_s and Q_p . $R_p = 98$ ohms and L_p is approximately equal to L_s . Note that R_p is a property

of the inductor and R_p on the schematic is not an installed component.

R_p is about 100 ohms. In order to match the input and output of the resonant circuit to 50 ohms, we can make R_p part of a 50 ohm T-Network attenuator

■ FIGURE 2. Series to Parallel Equivalent of Inductor Resistance.



EQUATIONS 1

Design Equations for the Resonant Circuit.

- $F_c = 4.19304$ MHz
- $w = 2 * 3.14 * F_c$
- $Q = 5$
- $Q_p = 110$
- $R = R_{load} = R_{source} = 50$ ohms
- $X_p = (R/2) * (Q_p - Q) / (Q_p * Q) = 4.773$
- $L_r = X_p / w = 180$ nH
- $C_r = 1 / (X_p * w) = 7.96$ nF

EQUATIONS 2

Design Equations for R_p .

- $R_s = (16.2)/(1000) * .5 = .008$ ohms
- $Q_p = 110$
- $R_p = Q_p^2 * R_s = 98$

TABLE 1

Design Values Corresponding to Operating Frequency.

Fc (MHz)	C1 (pF)	C2 (pF)	Vpp (out)
1.8	470	220	880 mV
2	390	150	880 mV
2.4	390	150	880 mV
3.5	390	150	880 mV
4.19	220	100	880 mV
5	220	100	880 mV
8	100	47	880 mV
10	47	22	880 mV
12	47	22	725 mV
16	33	15	580 mV
20	22	10	435 mV
25	22	10	290 mV

PARTS LIST

PART DESIGNATION

- ☐ R1,R2
- ☐ R3
- ☐ R4
- ☐ R5,R6
- ☐ R7,R8
- ☐ C_{tune}
- ☐ C1,C2
- ☐ C3,C5,C7
- ☐ C4
- ☐ C6
- ☐ Cr
- ☐ L_r
- ☐ L1
- ☐ J1
- ☐ X1

PART VALUE

- 56K 5% 1/4W
- 1K 5% 1/4W
- 5600 5% 1/4W
- 51Ω 5% 1/4W
- 10Ω 5% 1/4W
- 6.8-45 pF
- See text
- 100 nF
- 47 pF
- 1 μF
- See text
- See text
- 100 μH 10%
- BNC jack
- 2-25 MHz crystal

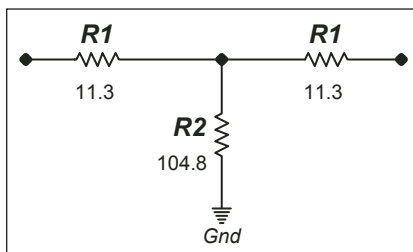


FIGURE 3. Schematic of a 4 dB T-Network Attenuator (50 ohms).

been constructed, the resonant circuit composed of L_r and C_r can be "tuned" to achieve maximum output voltage. Simply connect an oscilloscope to the 50 ohm output and adjust the coil spacing of inductor L_r for

peak signal output.

Oscillator Output Parameters

Next, we will find the total attenuation of the signal at the output of the

buffer to the output with a 50 ohm load connected. Attenuation in dB = $20 \cdot \text{LOG} (V_{out}/V_{in})$; 6 dB of attenuation is present because the output voltage with a 50 ohm load connected is one-half the no-load output voltage. Another 4 dB of attenuation is due to the T-Network attenuator. This is a total attenuation of 10 dB from the buffer output to the voltage

present across the 50 ohm load.

To verify the output voltage of Figure 1 with a 50 ohm load, first measure the RF signal present at the emitter of Q2 (in our example, this voltage is 2.75 Vpp). Using the attenuation equation:

$$-10\text{dB}/20\text{dB} = \text{LOG} (V_{out}/V_{in})$$

$$V_{out} = 2.75 \cdot 10^{-1/2}$$

Solving for V_{out} yields .87 Vpp. This calculated value for V_{out} agrees closely with the measured value of .84 Vpp.

Designing Your Own Oscillator

When designing your crystal oscillator, first choose a crystal. If your frequency is between two of the listed frequencies in Table 1, use linear interpolation to determine values for C1, C2, and the output voltage. The voltages listed in Table 1 are approximate. Then, follow the steps as indicated in the previous design example to determine your oscillator components. Have fun building and using your own crystal oscillator. **NV**

SOURCES

■ 1) R. Dean Straw, N6BV, *The ARRL Handbook, Calculating Practical Inductors*, 1999, p. 6-22, The American Radio League

■ 2) Chris Bowick, *RF Circuit Design, Single-Layer Air Core Inductor Design*, 1982, p. 17, Butterworth-Heinemann

■ 3) R. Dean Straw, N6BV, *The ARRL Handbook, T-Network Attenuators*, 1999, p. 30-24, The American Radio Relay League

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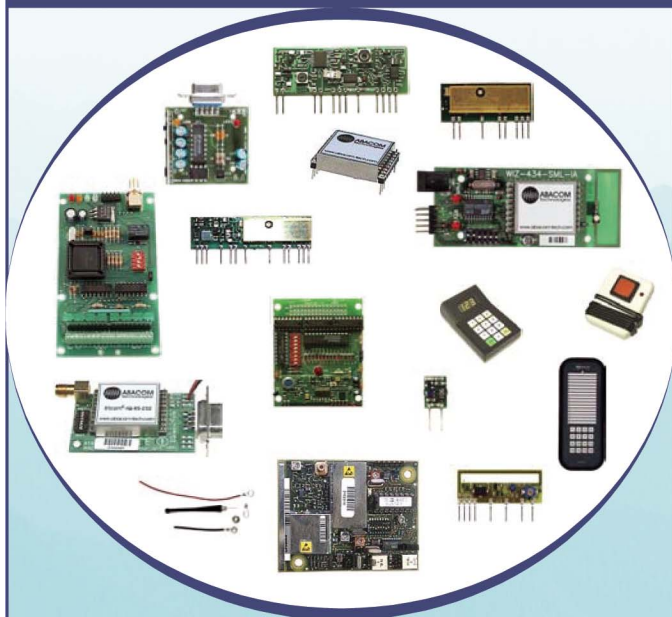


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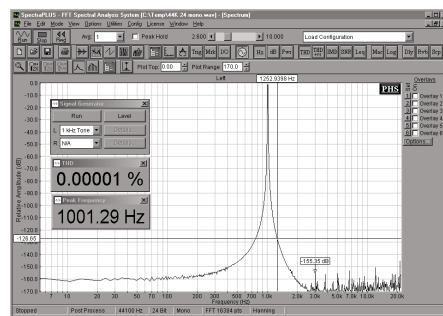


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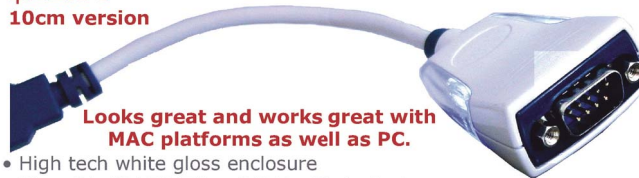


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Photo courtesy of Pepper Computing, Inc.

Have you heard about the Pepper Pad from Pepper Computer, Inc. (www.pepper.com), and Hanbit Electronics Co., Ltd. (www.hbe.co.kr)? Okay, you've heard about Microsoft Corporation's Origami project, right? Well, the Pepper Pad is just like Origami, but it's cheaper, uses an open-source Linux operating system, and it's available now.

Although Pepper Pad has been operating under the radar screen for the last couple of years, it's now ready for prime time with the release of a new Web player model. Dubbed Pepper Pad 3 Web Player, this latest incarnation of the familiar handheld entertainment device form factor features Wi-Fi and USB connectivity, a built-in Web camera, a seven-inch touch screen, integrated joystick/keyboard, a 20 Gb hard disk drive, and stereo speakers and microphone.

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Powering all of this gusto is an embedded AMD Geode™ LX 800 microcontroller running a Linux Kernel 2.6 OS.

Likewise, a handsome suite of software enables this worthy Web player to stream and download and play music, videos, movies, and photos through a suitable Wi-Fi network connection. Based on our extensive tests, the video playback capability of the Pepper Pad is outstanding, rivaling many portable DVD players. Furthermore, the integrated "prop" stand enables the Pepper Pad to play a movie to a much larger audience — hands free.

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Believe it or not, there is a ZigBee Alliance (www.zigbee.org). This global association of hardware manufacturers and technology providers is headstrong on creating yet another wireless "solution" for use in the home, commercial, and industrial venues.

Recently, the ZigBee Alliance's Second Annual Developers' Conference was held in Rosemont, IL on June 5-7 in conjunction with Sensors Expo and Conference. During this three-day event, developers learned methods for incorporating ZigBee wireless sensor and control networks into new products.

There were ZigBee compliant platforms, transceivers, microcontrollers, network stacks, and developer tools for conference attendees to test, evaluate, and compare. This interactive environment enabled developers to "jump start" future ZigBee product development and subsequent product market entry.

Regardless of what you may think about ZigBee, this new technology is an interesting low-cost, low-power wireless standard that is gaining international acceptance for remote sensing.

AND ZIGBEE FOR ALL

If you're looking for a way to dip your toes into the ZigBee pool, Cirronet™, Inc. (www.cirronet.com), is now offering the ZigBee Basic Developer Kit. This low-priced

development tool enables network designers to rapidly evaluate the ZigBee wireless standard within their specific application environment.

The ZMN24HPDK-B (Basic) Developer Kit includes one RS-232 wireless sensor modem and one 2.4 GHz sensor interface board, both equipped with the Cirronet's 2.4 GHz high RF

power (100 mW) ZigBee OEM module, plus power adapters, cables, antennas, batteries, and demo software. You can use the kit to test range, speed, and operation of a sample application within your real-world application environment.

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READER FEEDBACK

Continued from page 6

Freescal Semiconductor www.freescal.com/zigbee. However, these were evaluation boards designed to allow a developer to prove their application before manufacturing their own boards.

The board which Panasonic sells is based upon Freescale's ZigBee platform and is actually a production board, not an eval board. For example, you could acquire the eval kit from Freescale,

develop your application, and then run it on the Panasonic board in production mode, as the processor and relevant hardware are the same. You should note, that the Panasonic board has been FCC certified, which would be a requirement if you are going to incorporate the board in a product you are selling.

In fact, we used both the BDM hardware and the serial port. If you

download the software evaluation kit (or just the documentation) from the Freescale site, there are several examples which take you through using either mechanism. Hope this helps. — **Phil Davis**

ALTERNATIVES TO (HEAT) SINK YOUR TEETH INTO

I'm glad I took a subscription so I never miss an issue of your great magazine. The July issue that just arrived here in the Swiss Alps was once again this marvelous mixture from background information, projects, and how-to articles. Thank you for your excellent work!

The article from H.Ward Silver on "Choosing a Heatsink" (NV 27/7, pp 67-69), for example, is a very concise and hands-on guideline for the serious hobbyist. All relevant aspects of the question are addressed, the calculations presented, the results summarized, and the necessary links to vendors and additional information is given. Congratulations to the author!

In everyday life, it might nevertheless be interesting to take a slightly broader view on the task at hand: You have a 12V source and need to feed a stabilized 5V @ 0.5A to your circuit. One solution is to take a 7805 and a heatsink (calculated with the help of Mr. Silver). But there is another solution: Take three 7805 and forget about the heatsink! From the graphics in the "Typical Performance Characteristics" section of the 7805's datasheet, you can see that a 7805 in a TO-220 case may safely dissipate about 2W at 35° ambient temperature without heatsink. We need to dissipate 3.5 W in total, and we want to have a generous safety margin (even though that might be overcautious since the 7805 already has its own internal thermal protection circuitry). Two 7805s could dissipate 4W (just above the required limit), three will therefore be a good choice.

A rough calculation shows that this approach may be beneficiary on

Continued on page 94

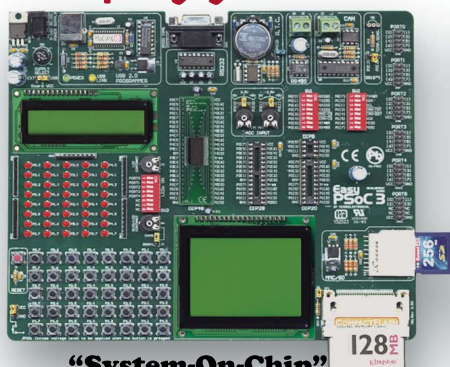
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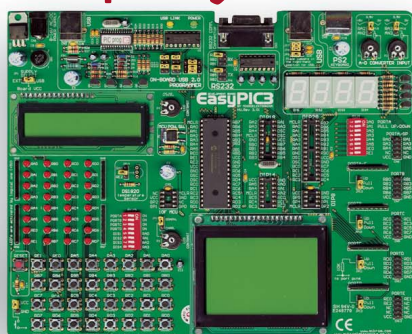
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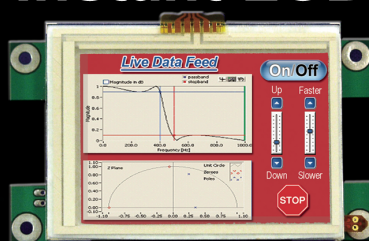
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UNDERSTANDING

Digital Logic ICs

PART 2 — The '74'-Series of Digital ICs

Ray Marston takes a deeper look at the '74'-series of digital ICs, and at various sub-members of its TTL and CMOS families, in this installment.

BY RAY MARSTON

Modern digital electronics are dominated by two major logic IC families: the low-speed '4000-series' of CMOS ICs and the '74-series' of fast TTL and CMOS ICs. The 74 family was originally based entirely on TTL technology, which first hit the electronics scene in a big way around 1972, when the 74-series suddenly arrived in the form of an entire range of versatile and cleverly conceived TTL digital logic ICs that were each designed to operate from a single-ended five-volt supply and to directly and easily interconnect with each other without hassle (each output could directly drive several inputs). This made it relatively easy for any moderately competent engineer to design and develop fairly complex digital logic systems. The series was an instant and brilliant international success, and almost immediately became the world's leading IC logic system. Its ICs were produced in both commercial and military grades, and carried prefixes of 74 and 54, respectively; the commercial product range rapidly became known simply as the 74-series of ICs.

A major feature of the 74-series is that all devices within the range function as black boxes that operate at similar input and output threshold levels; the user does not need to understand their internal circuitry in order to use them, but simply needs to know their

basic usage rules. Also, the input sensitivity or 'fan-in' of each device conforms to a fixed standard, and its output drive capability or 'fan-out' has a guaranteed minimum value that indicates the number of external 74-series inputs that it can safely directly drive, making it very easy to interconnect various devices. The output of a 74 gate with a fan-out of 10 can directly drive as many as 10 parallel-connected standard inputs on other 74-series ICs.

The type of TTL technology used in the initial (1972) 74-series ICs resulted in a range of devices that were moderately fast but consumed fairly heavy currents. Within a year or so, sub-families of the original TTL were introduced, offering a trade-off between speed and power, i.e., twice the speed but at twice the current consumption (in the H or high speed sub-family), or one-tenth of the current consumption but only one-third of the normal speed (in the L or low power sub-family), etc.

This trend of seeking a good or ever-better trade-off between speed and power consumption has continued until present day, and so far, a total of eight commercially successful sub-families of TTL (and five sub-families of CMOS) have appeared in the 74-series of digital ICs. Many of these sub-families have subsequently become obsolete or obsolescent, but the

practical design/maintenance engineer or technician still needs a basic knowledge of all of them, since they are often found in old equipment that needs repairing or upgrading.

Note that each sub-family of the 74-series of ICs is almost directly compatible with all other sub-families in the series. Thus, if you open up an old piece of equipment and find (for example) that an old 74L90 decade counter IC needs replacing but is no longer available, you will probably find that a modern 74LS90 decade counter IC can be used as a direct plug-in replacement, or that any other 74XX90 ICs can be used as a replacement either directly or with slight circuit modification (depending on the basic characteristics of the two sub-families). In either case, the first thing that you will need to do is identify the device of interest from its printed code number. Figure 1 explains the basic scheme that is used in formatting the 74-series code numbers.

All ICs in the 74 family are identified by an alpha-numeric code which — in its simplest form — consists of three sub-codes strung together as shown in Figure 1. The first (left hand) sub-code consists of two digits that read either 74, 54, or 75. The 74 identifies the IC as a commercial-grade member of the family. These devices are usually encapsulated in a plastic 14-pin, 16-pin,

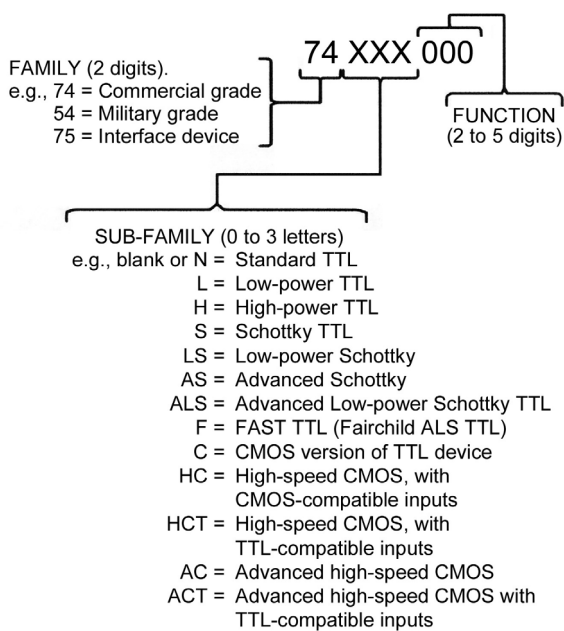


FIGURE 1. Basic coding system used on the 74-series ICs.

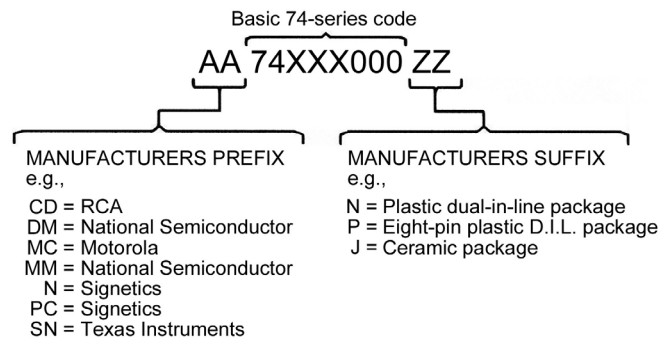


FIGURE 2. The basic 74-series code is often elaborated with a manufacturer's prefix and/or suffix.

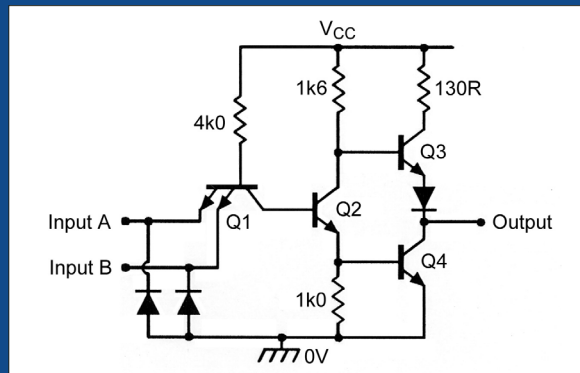


FIGURE 3. Circuit of a Standard TTL 7400 two-input NAND gate.

or 24-pin dual-in-line package (DIP), can be used with supplies within the limit +4.75 V to +5.25 V, and can be operated over the temperature range 0° C to +70° C. The 54 identifies the IC as a high-quality military-grade member of the family. These devices are encapsulated in exotic packages, can use supplies within the limit +4.5 V to +5.5 V, and can operate over the temperature range -55° C to +125° C. The 75 identifies the IC as a commercial-grade interface device that is designed to support the 74 range of devices.

The second (central) sub-code consists of up to three letters, and identifies the precise technology or sub-family used in the construction of the device, as shown in the diagram. Note that standard TTL devices carry either no central code at all, or an N. Each of the other seven major TTL sub-family devices carry a central identifying code, and the five major CMOS 74 sub-families carry a central code that includes the letter C.

The last (right hand) sub-code usually consists of two to five digits (but occasionally includes a letter A or a star), and identifies the precise function of the IC (e.g., quad two-input NAND gate, decade counter, four-bit

shift register, etc.). The precise relationship between this sub-code and the device function can be ascertained from the manufacturer's lists.

Thus, a 74 type of IC may carry a code that, in its simplest form, reads something like 7400, 74N00, or 7414, etc., if it is a standard TTL device, or 74L14, 74LS38, or 74HC03, etc., if it is some other sub-member of the 74 family. Note that in practice 74-series ICs often carry an elaborated form of the basic code that includes a two-letter pre-fix that identifies the manufacturer, plus a lettered manufacturer's suffix that indicates the packaging style, etc., as shown in Figure 2. Hence, a device marked SN74LS90N is a normal 74LS90 IC, manufactured by Texas Instruments and housed in a plastic DIP.

TTL Sub-Families

Eight major sub-families of TTL have been used in the 74-series throughout its lifetime, as follows:

Standard TTL — Standard TTL is similar to the basic type already described, except that each of its inputs are provided with a protection diode that helps suppress transients and speeds

up its switching action. Figure 3 shows the actual circuit of a 7400 two-input NAND gate. Its power consumption is 10 mW, and its propagation delay is 9 nS when driving a 15pF/400Ω load.

Low-Power (L) TTL (now obsolete) — Low-power TTL is a modified version of the standard type, with its resistance values greatly increased to give a dramatic reduction in power consumption at the expense of reduced speed. Figure 4 shows the circuit of a 74L00 two-input NAND gate. Its power consumption is 1 mW, and its propagation delay is typically 33 nS.

High-Speed (H) TTL (now obsolete) — High-speed TTL is a modified version of the standard type, with its resistance values reduced to give an increase in speed at the expense of increased power consumption. Figure 5 shows the circuit of a 74H00 two-input NAND gate. Its power consumption is 22 mW, and its propagation delay is typically 6 nS.

Schottky (S) TTL (now obsolete) — A transistor switch can be designed to give either a saturated or an unsaturated switching action. Saturated

switching — in which the transistor's collector voltage falls far below that of the base under the on condition — is very easy to implement, but produces propagation delays that are about 2.5 times longer than those available from unsaturated circuits.

Standard TTL operates its transistors in a heavily-saturated switching mode in which the collector falls some 400 mV below the base under the on condition, and is thus intrinsically slow. Schottky TTL, on the other hand, operates its transistors in a lightly-saturated switching mode in which the collector only falls some 180 mV below the base voltage under the on condition, and is almost as fast as an unsaturated circuit (such as an ECL design).

Basically, this action is achieved by connecting a Schottky diode (which is fast-acting and has a typical forward volt drop of only 180 mV) between the transistor's collector and

circuit of a 74S00 two-input NAND gate. Its power consumption is 20 mW and its propagation delay is 3 nS when driving a 15pF/280Ω load.

Low-Power Schottky (LS) TTL — Low-power Schottky uses a modified form of Schottky technology, using improved manufacturing techniques, combined with a diode-transistor (rather than multi-emitter) form of input network that has a high impedance and gives fast switching. Figure 8 shows the circuit of a 74LS00 two-input NAND gate. Its power consumption is 2 mW and its propagation delay is 8 nS when driving a 12pF/2K load.

Advanced Low-Power Schottky (ALS) TTL — This sub-family is similar to LS but uses an advanced fabrication process which, combined with minor design modifications, yields active devices that are faster and have high-

CMOS 74-Series Sub-Families

When the 74-series of ICs were first released in 1972, all devices in the range were based on bipolar TTL technology, which inherently consumes a fairly large amount of power, irrespective of its operating speed. In about 1975, the rival CMOS digital ICs technology arrived on the scene, and although it was not as fast as TTL, it offered the outstanding advantage of having a power consumption that was directly proportional to operating speed, being virtually zero under quiescent conditions and rising to the same value as TTL at about 10 MHz. In the late 1970s, CMOS was introduced as a sub-family within the 74-series range of devices, carrying the central code C. The graph in Figure 11 compares the frequency/current-consumption curves of a single gate from the standard TTL

“Modern digital electronics are dominated by two major logic IC families: the low-speed ‘4000-series’ of CMOS ICs and the ‘74-series’ of fast TTL and CMOS ICs.”

base as shown in Figure 6(a), in which R_s represents the input pulse's source impedance. Thus, if the collector goes more than 180 mV negative to the base, the Schottky diode becomes forward-biased and starts to shunt base current directly into the transistor's collector, thus automatically preventing deeper saturation. In reality, the Schottky diode can easily be incorporated in the transistor's structure, and a 'Schottky-clamped transistor' of this type uses the symbol shown in (b).

In a practical Schottky TTL IC, Schottky-clamped transistors are widely used, and most resistance values are reduced, thus giving a good increase in speed at the expense of power consumption. The totem-pole output stage uses a Darlington transistor pair to give active pull-up, plus a modified active pull-down network that gives an improved waveform-squaring action. Figure 7 shows the

er gains than LS types. Figure 9 shows the circuit of a 74ALS00 two-input NAND gate. Its power consumption is 1 mW and its propagation delay is 4 nS when driving a 50pF/2K load.

Advanced Schottky (AS) TTL — This sub-family is similar to ALS, but its design is optimized to give very high speed at the expense of power consumption. Figure 10 shows the circuit of a 74AS00 two-input NAND gate. Its power consumption is 22 mW and its propagation delay is a mere 2 nS when driving a 50pF/2K load.

FAST (F) TTL — FAST (Fairchild Advanced Schottky TTL) is Fairchild's version of 'AS' TTL. It is manufactured under license by several companies (including Philips and National Semiconductor). Its performance is similar (in terms of speed and power consumption) to that of the AS sub-family.

and the CMOS C versions of the 7400 quad two-input NAND gate IC.

In its early form, the 74-series C sub-family was slow and had a very weak output-drive capability (its fan-out drive was equal to two L type inputs). In subsequent years, however, considerable improvements took place in both the design and production of CMOS-type devices. The salient details of this subject will be covered in greater detail in Part 4, but in the meantime, it is sufficient to know that a total of five CMOS sub-families have been introduced in the 74-series, as follows:

Standard (C) CMOS (now obsolete) — This sub-family was virtually normal CMOS in a 74-series format. Typically, a single 74C00 two-input NAND gate consumed about 15 mW at 10 MHz, and had a propagation delay of 60 nS.

High-Speed (HC) CMOS — In the

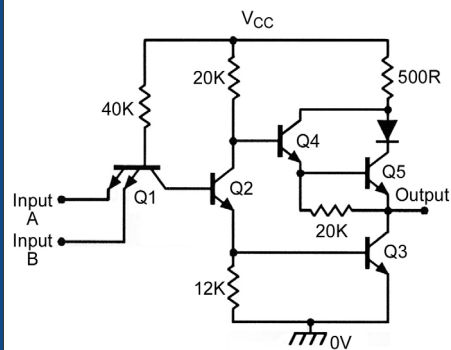


FIGURE 4. Circuit of a low-power (L) TTL 74L00 two-input NAND gate.

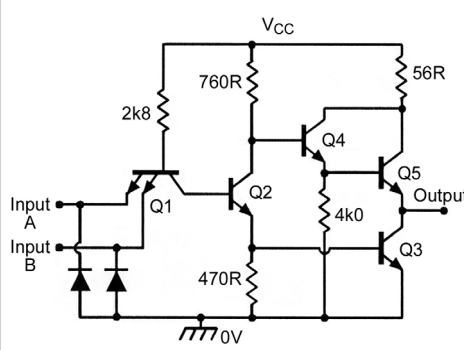


FIGURE 5. Circuit of a high-speed (H) TTL 74H00 two-input NAND gate.

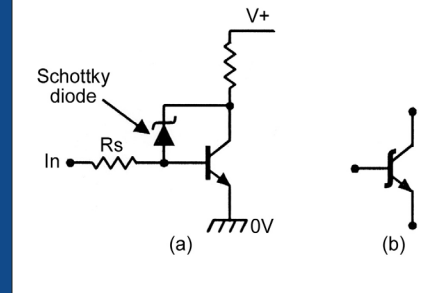


FIGURE 6. (a) A Schottky diode used to limit the saturation depth of an NPN transistor; (b) Symbol of an NPN 'Schottky' transistor, with a built-in clamping diode between its collector and base.

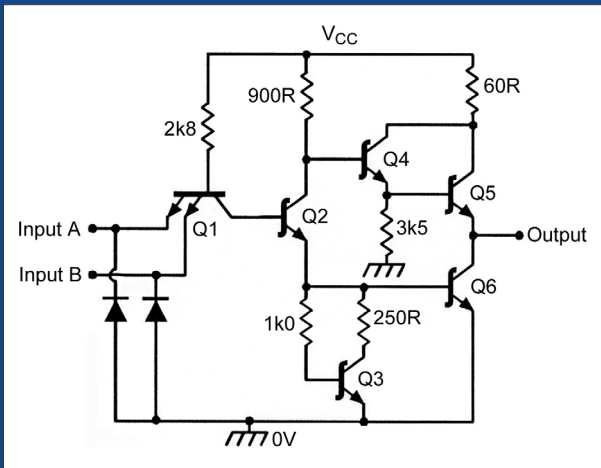


FIGURE 7. Circuit of a Schottky (S) TTL 74S00 two-input NAND gate.

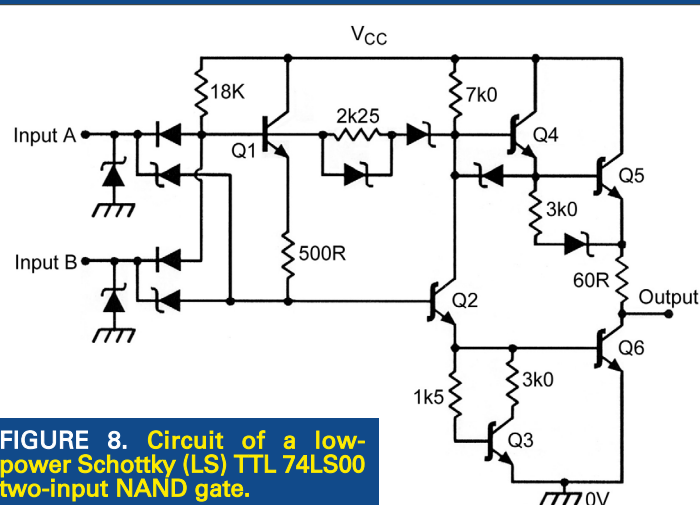


FIGURE 8. Circuit of a low-power Schottky (LS) TTL 74LS00 two-input NAND gate.

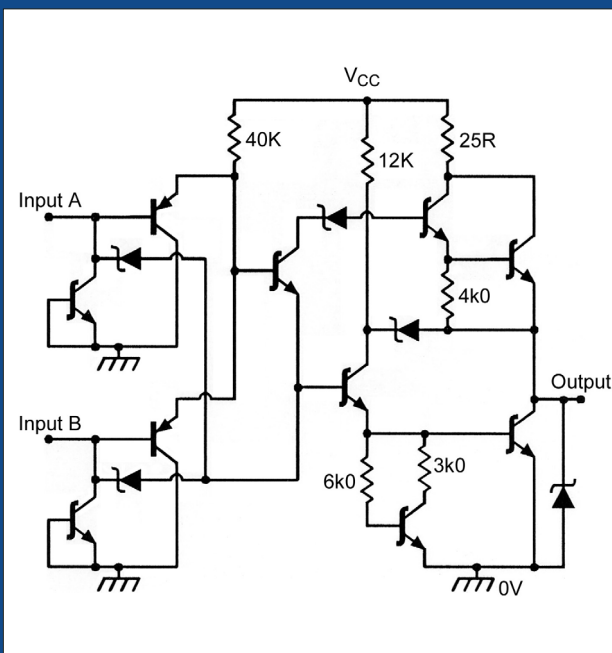


FIGURE 9. Circuit of an advanced low-power Schottky (ALS) 74ALS00 two-input NAND gate.

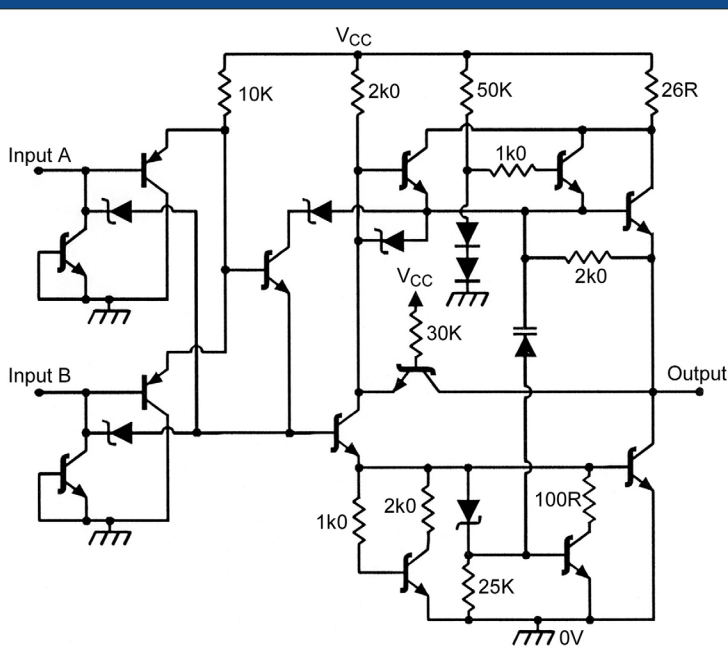


FIGURE 10. Circuit of an advanced Schottky (AS) TTL 74AS00 two-input NAND gate.

early 1980s, advances in CMOS fabrication techniques yielded speed performances similar to LS TTL, but with CMOS levels of power consumption. HC 74-series devices using this technology have CMOS-compatible inputs. Typically, a single 74HC00 two-input NAND gate consumes less than 1 μ A of quiescent current, and has a propagation delay of 8 nS.

High-Speed (HCT) CMOS — These are HC-type devices, but have TTL compatible inputs. Typically, a 74HCT00 two-input NAND gate consumes less than 1 μ A of quiescent current and has a propagation delay of 18 nS.

Advanced High-Speed (AC) CMOS — In the late 1980s, advances in CMOS design and further advances in CMOS fabrication techniques yielded speed performance similar to those of ALS. AC 74-series devices using this technology have CMOS-compatible inputs. Typically, a 74AC00 two-input NAND gate has a propagation delay of 5 nS.

Advanced High-Speed (ACT) CMOS — These are AC-type devices, but have TTL-compatible inputs. Typically, a 74ACT00 two-input NAND gate has a propagation delay of 7 nS.

Which Logic Family is Best?

Two major general-purpose logic families are currently available: the 4000-series low-speed CMOS family and the high-speed 74-series TTL/CMOS family (a third family, using ECL technology, is very specialized and intended for use in very high-speed applications). The 4000-series (which will be described in Part 4) is of particular value in circuits operating below frequencies of a few MHz in which a minimal figure of quiescent current consumption is desired. Other major advantages of the series are that its ICs can operate from any supply in the 3 to 15 V range, have excellent noise immunity, and have ultra-high input impedances.

The 74-series is of special value in circuits operating at frequencies up to several tens of MHz, in which low

quiescent current consumption is not too important and in which the ICs can be powered from a well-regulated DC supply (typically of +5 V). If you decide to use a 74-series IC, you are faced with the problem of deciding “which sub-family is best for my application?”

Which 74-Series Sub-Family is Best?

When designing a new logic circuit, ICs should always be selected on a basis of commercial (rather than purely technical) superiority. It would, for example, be foolish to use a really fast ALS gate in an application in which a slower LS or HC device would be perfectly adequate and was readily available at a fraction of the cost of the ALS device. With this point in mind, note that the five 74-series IC sub-families most widely available at the time of writing are Standard and LS TTL, and HC, HCT and AC CMOS. Of these, Standard TTL is technically and commercially inferior to LS and is not recommended for use in new designs. The AC CMOS cost approximately 2.5 times as much as LS TTL or HC/HCT CMOS and should thus only be used in special applications. HCT is only meant to be used as a replacement for TTL devices in existing designs and should not really be used in new designs. That leaves just LS TTL and HC CMOS.

Of these two 74-series sub-families, LS is slightly faster than HC and is available in a far greater range of functional device types, but generally consumes more supply current/power than HC at frequencies below about 5 MHz. (Figure 12 compares the performances of 74LS00 and 74HC00 gates.) Thus, for most new design applications, the LS TTL and HC CMOS sub-families deserve a joint ‘best’ award, with a slight edge perhaps going to LS.

TTL Logic Levels and Noise Immunity

All digital ICs handle input and output signals that switch between the high (logic-1) or low (logic-0) states. In TTL, each of these logic levels must fall within a defined range of voltage lim-

its. Figure 13 shows the typical input-to-output voltage curve of a Standard TTL inverter that operates from a +5 V supply and has a lightly loaded output. Note that the output is high, at +3.5 V, until the input rises to 0.7 V, and then falls fairly linearly as the input is further increased, and eventually stabilizes at a low value of about 0.25 V when the input rises above 1.5 V.

In practice, all Standard and LS TTL ICs are — when using a +5 V supply — guaranteed to recognize any input voltage of up to 0.8 V as being a logic-0 input, and of 2.0 V or above as being a logic-1 input. Note that the area between these two levels is known as the IC’s indeterminate zone or region, and operation within this zone should be avoided.

In TTL circuitry, different logic levels are used to define input and output signals, since TTL output voltage levels vary considerably with loading conditions. Figure 14 shows how — when an input of 0.4 V is applied to the above TTL inverter — the logic-1 output voltage falls from +3.5 V at near-zero load current, to a mere 2.0 V at a load current of 13 mA, and so on. In practice, all Standard TTL ICs are guaranteed (when using a +5 V supply) to recognize any output voltage of up to 0.4 V as being a logic-0 output, and of 2.4 V or above as being a logic-1 output. On LS TTL ICs, these levels are 0.5 V for logic-0, and 2.7 V for logic-1.

When one TTL output is connected directly to a following TTL input, any excessive noise on the output signal may cause incorrect operation of the following input stage. Thus, taking a worst-case situation, a logic-1 Standard TTL output may be as low as 2.4 V, and any superimposed negative-going noise pulse greater than 0.4 V will drive the following input below the 2.0 V ‘logic-0’ defined threshold and may cause it to erroneously recognize its input as being a logic-0 (rather than logic-1) signal.

The maximum worst-case magnitude of noise that a digital IC can ignore under these conditions is known as its noise immunity or noise margin value, and equals the difference between the logic-0 or logic-1 output/input threshold values. With Standard TTL, noise

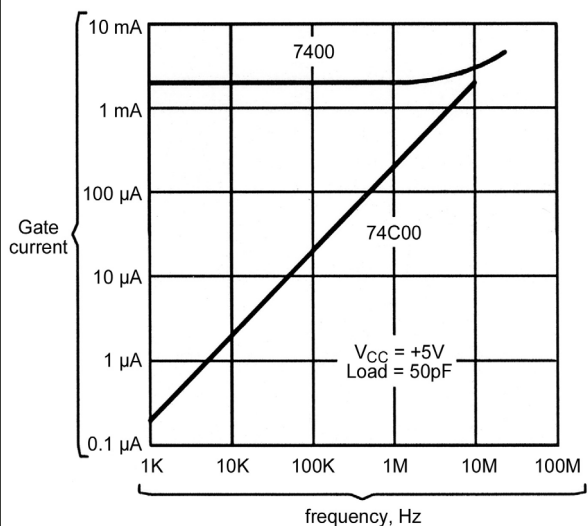


FIGURE 11. Frequency-current graphs of 7400 (TTL) and 74C00 (CMOS) two-input NAND gates (with a squarewave input).

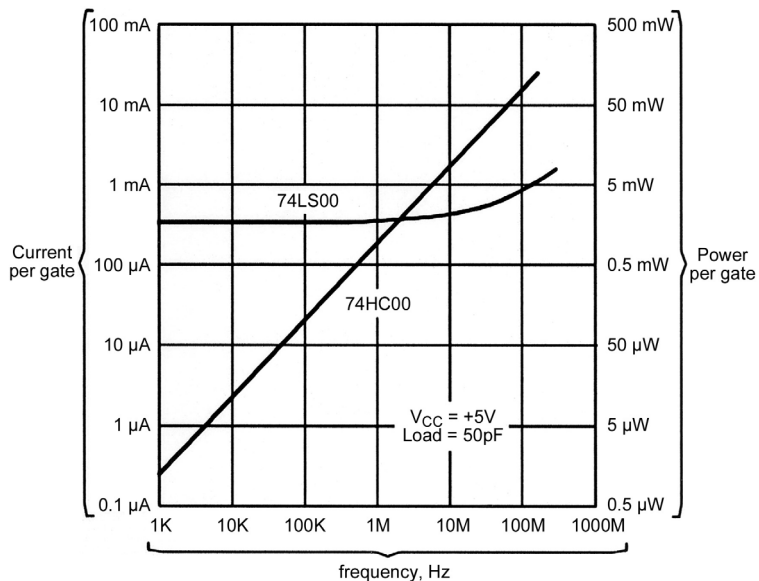


FIGURE 12. Frequency versus current/power graphs of 74LS00 and 74HC00 two-input NAND gates (with a square wave input).

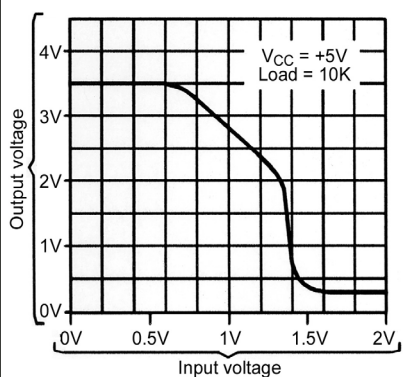


FIGURE 13. Standard-TTL input-to-output voltage graph.

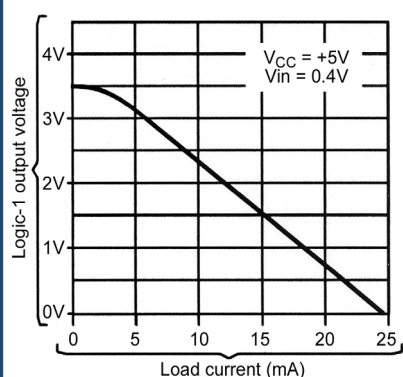


FIGURE 14. Standard-TTL logic-1 output voltage-current graph.

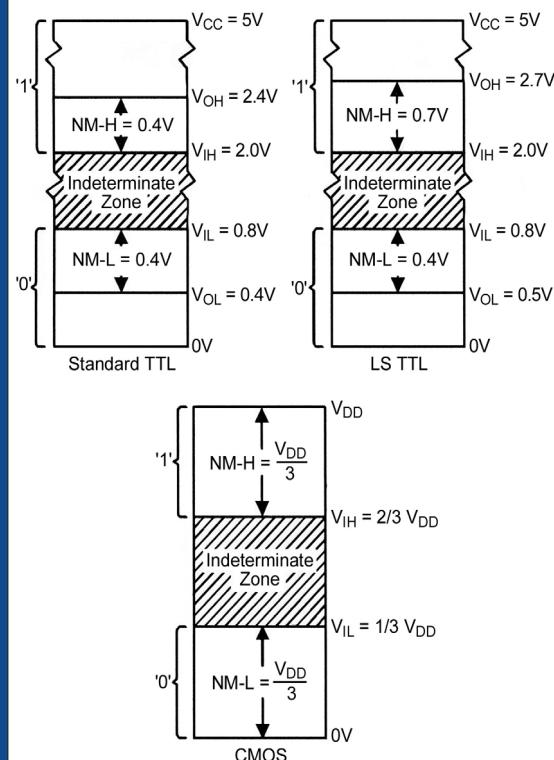


FIGURE 15. Logic level and noise margin values of Standard TTL, LS TTL, and CMOS.

PARAMETERS	74-Series TTL Sub-families							UNITS
	Standard	L	H	S	LS	AS	ALS	
Propagation Delay (2-input NAND gate)	9nS	33	6	3	8	2	4	nS
Power Dissipation (per gate)	10 mW	1	22	20	2	22	1	mW
V_{IH}	2.0V	2.0	2.0	2.0	2.0	2.0	2.0	V
V_{OH}	2.4V	2.4	2.4	2.7	2.7	$V_{DD}-2V$	$V_{DD}-2V$	V
NM-H	400 mV	400	400	700	700	700	700	mV
V_{IL}	0.8V	0.7	0.8	0.8	0.8	0.8	0.8	V
V_{OL}	0.4V	0.3	0.4	0.5	0.5	0.5	0.5	V
NM-L	400 mV	300	400	300	300	300	300	mV

FIGURE 16. Typical propagation delay and power dissipation figures for single 00-type NAND gates within the TTL sub-family ranges, together with sub-family voltage threshold and noise-margin values.

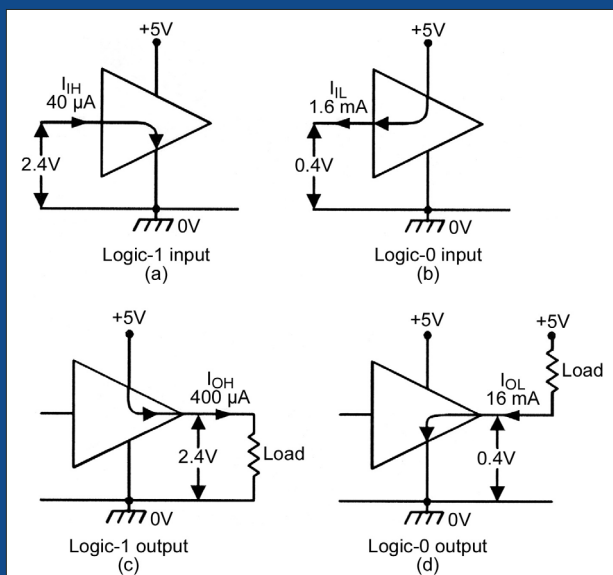


FIGURE 17. Basic input and output parameters of a Standard TTL logic element.

margins for both logic-1 (NM-H) and logic-0 (NM-L) have defined worst-case values of 400 mV. With LS TTL, the noise margins are 700 mV for logic-1, and 300 mV for logic-0. With CMOS, both margins have values of $V_{DD}/3$. Figure 15 illustrates the values of these three sets of threshold and margin values.

Figure 16 expands the above information and shows actual defined threshold voltage and noise margin values, together with typical propagation and power dissipation values for single 00-type two-input NAND gates, for the seven major sub-families of TTL (FAST TTL is regarded here as simply a minor variation of AS TTL).

Fan-In and Fan-Out

In TTL circuitry, an element's input drive requirements are known as its fan-in values, and its output driving capability limits are known as its fan-out values. Figure 17 illustrates the meanings and worst-case values of these items when applied to a Standard TTL element. Thus, (a) shows that when the TTL element is driven from a Standard TTL output stage, it draws a worst-case input current (I_{IH}) of $40\mu A$ when fed with a 2.4 V logic-1 input, but — as shown in (b) — feeds 1.6 mA (I_{IL}) into the driver when it provides a 0.4 V logic-0 input. Diagram (c) shows that the TTL element's output can, when in the logic-1 state, provide up to $400\mu A$ (I_{OH}) before its output voltage falls below 2.4 V; it is thus capable of feeding up to 10 Standard inputs, and is said to have a logic-1 fan-out ($= I_{OH}/I_{IH}$) of 10.

Similarly, (d) shows that the output stage can — when in the logic-0 state — absorb up to 16 mA before its output voltage falls below 0.4 V; it is thus capable of driving up to 10 Standard inputs, and is said to have a logic-0 fan-out ($= I_{OL}/I_{IL}$) of 10. Thus, the element has a worst-case fan-out of 10, and it

PARAMETERS	74-Series TTL Sub-families							UNITS
	Standard	L	H	S	LS	AS	ALS	
I_{OH}	400 μA	200	500	1000	400	2000	400	μA
I_{IH}	40 μA	10	50	50	20	20	20	μA
Fan-out, H	10	20	10	20	20	100	20	—
I_{OL}	16 mA	2.0	20	20	8.0	20	8.0	mA
I_{IL}	1.6 mA	0.18	2.0	2.0	0.36	0.5	0.2	mA
Fan-out, L	10	11	10	10	22	40	40	—
Worst-case fan-out	10	11	10	10	20	40	20	—

FIGURE 18. Fan-in and fan-out values of the major TTL sub-families.

PARAMETERS	74-Series TTL Sub-families						
	Standard	L	H	S	LS	AS	ALS
Fan-in, '1'	1	0.25	1.25	1.25	0.5	0.5	0.5
Fan-in, '0'	1	0.1125	1.25	1.25	0.225	0.3125	0.125
Fan-in, worst-case	1	0.25	1.25	1.25	0.5	0.5	0.5
Fan-out, '1'	10	5	12.5	25	10	50	10
Fan-out, '0'	10	1.25	12.5	12.5	5	12.5	5
Fan-out, worst-case	10	1.25	12.5	12.5	5	12.5	5

Notes:

$$\text{Fan-in, '1'} = \frac{I_{IH}}{40} \mu A$$

$$\text{Fan-out, '1'} = \frac{I_{OH}}{40} \mu A$$

$$\text{Fan-in, '0'} = \frac{I_{IL}}{1.6} mA$$

$$\text{Fan-out, '0'} = \frac{I_{OL}}{1.6} mA$$

Fan-in, worst-case = highest figure

Fan-out, worst-case = lowest figure

FIGURE 19. TTL fan-in and fan-out in terms of Standard TTL units.

Sub-family drivers	Sub-family inputs						
	Standard	L	H	S	LS	AS	ALS
Standard TTL	10	40	8	8	20	20	20
L	1.25	11	1	1	5.5	4	10
H	12.5	50	10	10	25	25	25
S	12.5	100	10	10	50	40	50
LS	5	40	4	4	20	16	20
AS	12.5	111	10	10	55	40	100
ALS	5	40	4	4	20	16	20

Note: Fan-out = lowest figure of: $\frac{I_{OL}(\text{driver})}{I_{IL}(\text{inputs})}$ and $\frac{I_{OH}(\text{driver})}{I_{IH}(\text{inputs})}$

FIGURE 20. Maximum number of TTL inputs that may be driven from any TTL sub-family output.

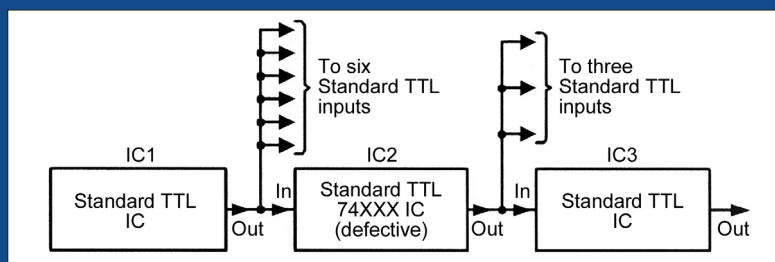


FIGURE 21. IC2 is defective; it is a Standard TTL device. Can it be replaced directly by a 74LSXXX IC? Figure 20 shows that the answer is yes.

can be used to directly drive as many as 10 Standard inputs.

Figure 18 presents the above data in tabular form, together with similar data for all other major TTL sub-families. When working within any one sub-family, note that the most important figure here is the 'worst case fan-out (F-O)' value. Thus, if you are (for example) designing a system based entirely on LS ICs, you can confidently connect an ordinary output directly to as many as 20 normal inputs, without risk of a malfunction due to overloading (if you need to drive more than 20 inputs, you can do so via one or more high-fan-out buffers, etc.). Note that, within any given sub-family, all ordinary inputs are said (in TTL jargon) to have a fan-in of unity (1), but that in practice some MSI or LSI ICs (such as counters and registers, etc.) may have special inputs (such as Reset or Preset, etc.) with fan-in values of two or greater.

Sometimes, an engineer may have to mix TTL sub-families, usually so that an obsolete IC can be replaced by a readily-available modern plug-in close-equivalent. In such a case, it is necessary to relate the fan-out data of one sub-family to that of another, to check that the mix can be made without causing an input or output overload. One easy way of doing this is to simply transpose the data of Figure 18 into 'Standard TTL' fan-in units, as shown in Figure 19, to gain an approximate idea of the relative fan values of various sub-families. Thus, it can be seen at a glance that LS TTL has only half of the fan-in requirement of Standard TTL, but also has only half of its fan-out capability, etc.

An even more useful way of applying the basic data of Figure 18 is to convert it into an easily-used form that relates the fan-in and fan-out data of each TTL sub-family to all other TTL sub-families, as shown in Figure 20. Here, by reading across the left-hand columns, it can (for example) be seen that a normal LS output can drive up to five Standard TTL inputs, and that a Standard TTL output can safely drive up to 20 LS inputs.

Thus, if an engineer is faced with a problem such as that illustrated in Figure 21 — in which a fault on an old Standard TTL circuit is traced to a

defective 74XXX-type IC (IC2) which is used to directly drive four other Standard TTL inputs — it can be quickly seen that a 74LSXXX plug-in equivalent IC can be safely used to directly replace the IC2 Standard TTL device without incurring overload problems.

TTL Basic Usage Rules

It is usually a fairly easy matter to

design logic circuitry using TTL ICs, providing that a set of TTL basic usage rules are observed. Assuming that the matter of fan-in and fan-out has already been taken care of, there are four basic usage themes outstanding, and these will be described in next month's installment, under the general headings of *Power Supplies, Input Signals, Unused Inputs, and Interfacing.* **NV**

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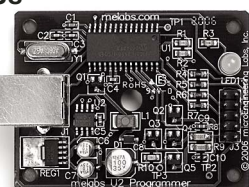
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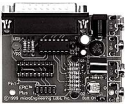
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- Requires 9-12VDC wall adapter Jameco #252751 \$12.05)



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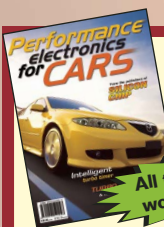
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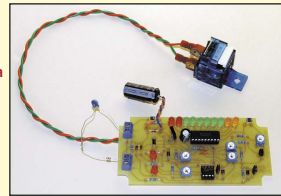
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by Edward B. Driscoll, Jr.

A Mixed Blessing

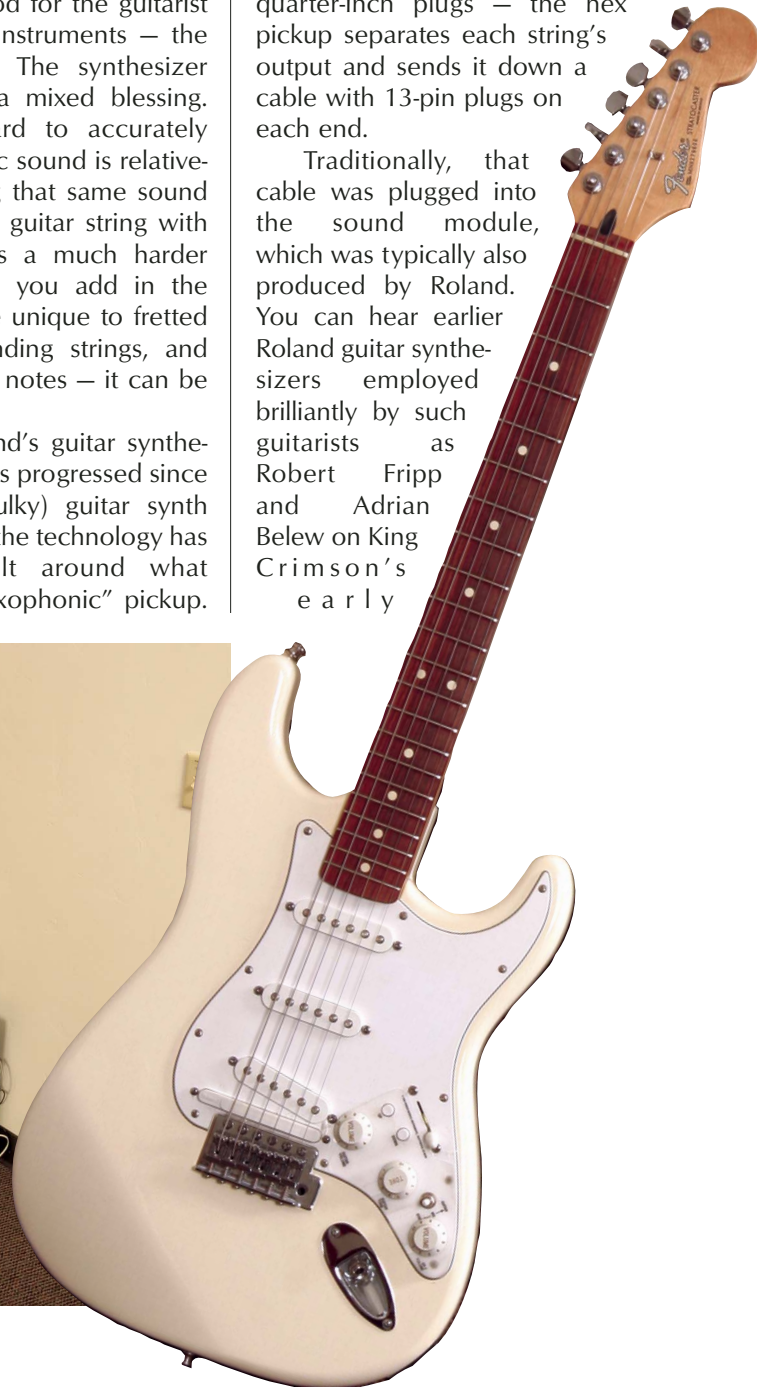
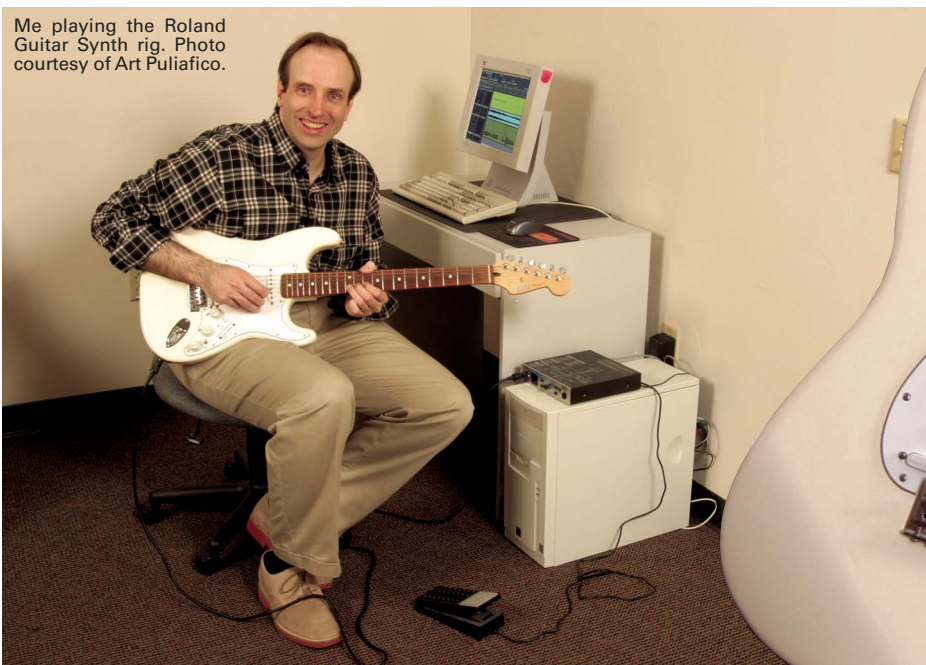
But there's far more to music than just the guitar, which is why, in the mid-1970s, Japan's Roland Corporation (www.rolandus.com) developed a method for the guitarist to simulate other instruments — the guitar synthesizer. The synthesizer has always been a mixed blessing. Getting a keyboard to accurately trigger an electronic sound is relatively easy, but getting that same sound from a finger on a guitar string with frets underneath is a much harder proposition. When you add in the techniques that are unique to fretted instruments — bending strings, and slurring and sliding notes — it can be doubly challenging.

Although Roland's guitar synthesizer technology has progressed since their first (very bulky) guitar synth rolled out in 1978, the technology has always been built around what Roland calls a "hexophonic" pickup.

In other words, unlike the traditional electric pickup that's built into every Gibson Les Paul and Fender Stratocaster — which combines the sound of all six strings into a single output through an audio cable with quarter-inch plugs — the hex pickup separates each string's output and sends it down a cable with 13-pin plugs on each end.

Traditionally, that cable was plugged into the sound module, which was typically also produced by Roland. You can hear earlier Roland guitar synthesizers employed brilliantly by such guitarists as Robert Fripp and Adrian Belew on King Crimson's early

Me playing the Roland Guitar Synth rig. Photo courtesy of Art Puliafico.



1980's albums *Discipline* and *Beat*, as well as by Andy Summers on several songs recorded by The Police from that same era.

Plug Into Your USB Port

But, in 2003, at the National Association of Music Merchants' trade show, Roland debuted the GI-20, a new box for their hex pickup to plug into.

The GI-20 isn't a sound module. Instead, it converts the hex pickup's data to MIDI information — the universal language of synthesizers. Meaning that a guitar can control just about any synthesizer.

But it also came with a USB output. Meaning that it's now possible to play your computer with your guitar.

Err, let me explain that. Since the 1980s, a variety of "software synthesizers" have been developed for Mac OS and Windows-based computers. Traditionally, these programs were played via a MIDI keyboard. But now, guitarists who want to get in the game have an input device.

There are essentially two ways to "play" the GI-20. Roland offers their GK-2A hex pickup as a bolt-on application for steel-strung acoustic and electric guitars, and licenses the technology to guitar manufacturers so that they can build Roland hex pickups into their own instruments.

One example is Fender's (www.fender.com) Roland-Ready Stratocaster, which mates their best-selling electric guitar with a built-in pickup and 13-pin jack. The factory-mounted pickup tracks a bit better than the GK-2A aftermarket pickup, since the former is precisely factory mounted precisely with the proper distance between the pickup and the strings. Other manufacturers make similarly equipped guitars, including Brian Moore (www.brianmooreguitars.com) and Godin (www.godinguiguitars.com).

Playing The Guitar Synth

Whether it's mounted on an

existing guitar via their GK-2A pickup or built into instruments like the Roland-Ready Strat, I found that Roland's synth pickup tracks remarkably well — in fact, probably too well. The fumbling finger noise that's taken for granted when playing an electric guitar translates into momentary "ghosts" and unwanted chromatic notes by the MIDI pickup. To compensate, many MIDI recording programs have a function called "deglitch," which will quickly become your best friend when you want to clean up a performance after recording guitar synth data.

Tuning, curiously, isn't as big a factor with synthesizers as it is when recording audio from a real guitar. I spend a considerable amount of time tuning a guitar before recording it, and "spot tune" it between takes. But, as long as the guitar being used to trigger the synth is in the ballpark, the tuning on the synthesizer (which is virtually always dead-on) will do the rest.

Bending notes can be a problem, though. Some software has a function that allows control over the rate that the software synth bends notes. But not all do, and it's hit or miss as to how closely the GI-20 can respond to coordinate with the software you're using for sounds.

In an odd way, though, this illustrates one of the beauties of MIDI recording: more so than with audio recording, it's possible to record a part, then move every note, often by just milliseconds. Or to take an individual note and shorten or lengthen it.



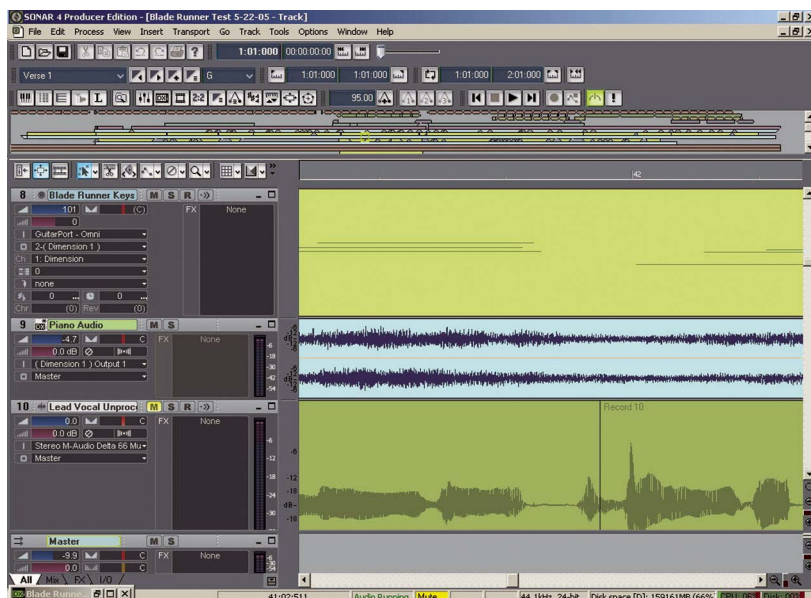
Close-up of the Roland GI-20 breakout box.

Or raise or lower its pitch.

Unless you're a classically trained guitarist with brilliant fingering technique, it's awfully difficult to play chords and melody lines simultaneously. This makes the guitar a very different instrument from a keyboard, whose player can easily play a melody with his right hand and hold down the rhythm with his left. But it's possible to do a pretty nifty impersonation of this technique with the guitar synth, by first playing the chords of a piano part and then going back and overdubbing a separate MIDI track of a melody part, or melodic fills. The Roland GI-20 even has a button (which can be remote-controlled by a foot switch) to raise or lower the octave that



The rig that was used. Photo courtesy of Art Puliafico.



Cakewalk's Sonar PC-based recording program is one example of the recording software that the Roland GI-20 can interface with.

the instrument is in.

As keyboard synthesists have known for decades, in order to accurately recreate a sound, it helps to have a sense of what an instrument can do. Every instrument has a high and low note to its range. And certain instruments require specific techniques that are worth emulating, unless you want to deliberately synthesize something a bit unreal. For example, unlike an electric guitarist, who can pick a lead solo for minutes at a time without pausing, horn players need to breathe while playing, which influences their phrasing and results in natural pauses in their lead lines.

Big Sounds From Software Synths

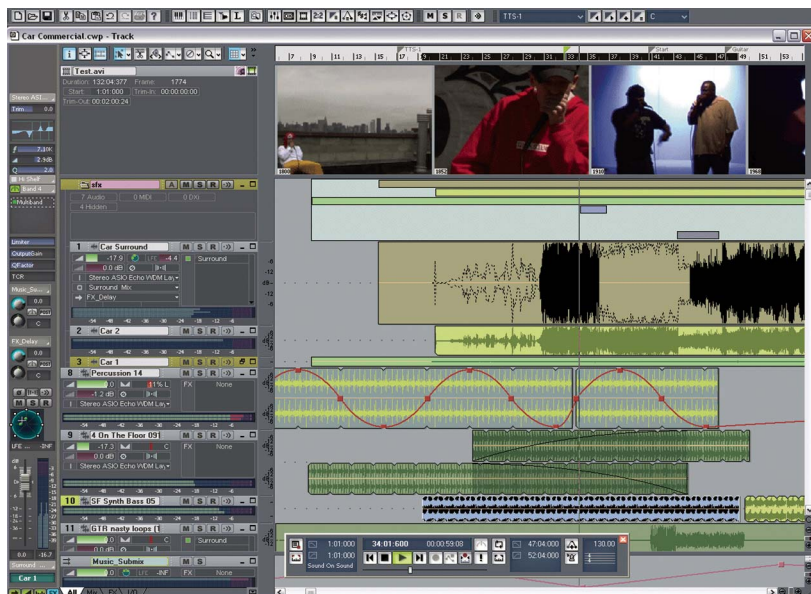
As I've said, the GI-20 is merely an interface. Its MIDI jacks can be plugged into almost any external synthesizer. But its real power is using its USB interface to drive software-based synthesizers on the computer.

As recent updates to popular software synthesizers have made the ability to achieve complex sounds much easier, the USB interface is all the more valuable. Two of the most popular examples of this technology are Propellerhead's Reason (www.propellerheads.se) and its upstart competitor, Cakewalk's Project5 (www.cakewalk.com). Both were updated with new versions.

Over the past five or six years, Reason has become the benchmark for software synthesizers. Its rack mount-style GUI makes it very easy for even a complete beginner to load up a synth or two and produce sounds very quickly.

The big feature in Reason Version 3.0 is a plug-in that makes getting those sounds even easier. Called "The Combinator," it comes with dozens of presets that daisy chain together an assortment of Reason's built-in virtual synths and effects to produce a variety of layered sounds — ranging from a full symphony orchestra, to ensembles of related instruments (such as brass, strings, and percussion), to all sorts of electronic-sounding instruments.

Songwriters looking to plug a brass or string arrangement into their songs should now find that much easier. A chord or a line played via the GI-20 (or a MIDI-equipped keyboard, of course) will result in a big, rich sound.



Meanwhile, Project5 includes a nifty new arranging feature of its own: an Arpeggiator with about a bazillion presets. If you've heard a tune like The Who's "Baba O'Riley," you've heard a single note synthesizer playing a sequenced pattern of arpeggios. Project5's Arpeggiator can reproduce these sorts of patterns with the preset sounds built into the program. Play one note on the MIDI-equipped guitar, and two, three, four, or more are produced by the Arpeggiator in a predetermined pattern.

Do Some Acid When Recording

No, not the kind of acid that fried Jerry Garcia's brain at Woodstock. The guitar synthesizer isn't the only way for a guitarist to import other instruments into a recording — acid is a form of looped audio sound.

For example, it can be very difficult to record live drums in a small apartment or a home with nearby neighbors. It can be even more difficult to find a live drummer good enough to perform solid time keeping. But Sony's Acid Collection (www.sonymediasoftware.com) includes numerous libraries of pristine recordings of drums, a few of which have been laid down by such superstar musicians as Mick Fleetwood, the leader of Fleetwood Mac. Best of all, tracks from the Acid Collection can be imported into many home recording programs — not just Sony's.

Putting It All Together

Home recording technology now allows any guitarist to be a one-man band, which is particularly useful for demo recording and songwriting. A home recording program, such as Cakewalk's Sonar (see the November '01 issue of *Nuts & Volts*), can incorporate digital audio, pre-recorded "loops" of audio, and MIDI synthesizers.

Thus, if a guitarist wants to make

a demo of a song to present to his rock group, he can use loops of drums to simulate a live drummer, play the bass line himself, play guitar, and use the Roland GI-20 and a guitar with a Roland-compatible synth pickup to simulate keyboards, sweeten the sound with violins, and include non-guitar lead instruments such as a sax or horns.

All of which can powerfully change what a home recording sounds like. Too many homemade demo tapes by guitarists are all guitar: power chords followed by lead guitar followed by chorused guitar followed by more power chords. The GI-20 — coupled with software synth programs, such as Project5 and Reason, and pre-recorded loops — opens up incredible new sonic vistas to guitar



players.

The question that remains is whether or not guitarists will open up to the possibilities of synths. Guitarists, for all their wildman strutting, are all too often technological Luddites, preferring that their equipment remains stuck in the era when Eric Clapton

first plugged a Les Paul into a

Marshall Amp, or Jimi Hendrix first asked the world, "Are You Experienced?" It's somewhat understandable, since incredible music was — and still is — recorded with instruments designed in the 1950s.

Nevertheless, there's amazing new music waiting to be made on guitar synths. But, enough talking. To paraphrase Frank Zappa's advice, it's time for me to shut up and play my guitar — and my computer, as well. **NV**

GuitarPort — Another USB Guitar Synth

Roland's GI-20 isn't the only way to transform the guitar into a synthesizer. Line6 (www.line6.com), which also manufactures a line of amps and effects boxes for guitarists, created a product called GuitarPort in 2002. This allows guitarists to plug their electric instruments into their computers via a small floor interface that connects the guitar's quarter-inch jack to the PC's USB cable.

From the start, most of the sounds that GuitarPort produced were modeled after vintage sounds of the '50s and '60s vacuum tube-powered amps beloved by electric guitarists for their warm tone and "musical" distortion when overdriven.

However, Line 6 began offering downloadable "Model Packs" for GuitarPort, to increase its

available sounds. Their "FX Junkie" pack allows for a variety of synthesizer sounds. While the synth patches don't always track properly (occasionally, they'll trigger a note an octave higher or lower than what it should be), there are plenty of sounds worth experimenting with, particularly for those who enjoy 1970s-era analog synth tones.

While GuitarPort has a decent built-in tuner, it also works very well with the Peterson StroboSoft tuner (www.strobosoft.com), which is a software version of their highly accurate strobe tuners. Using it with GuitarPort helps reduce the amount of ancillary equipment plugged in between the guitar and computer, which helps reduce accompanying ancillary noise.

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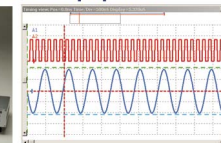


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Elf Turns 30

■ by Robert Armstrong -----> Part 1

It was 30 years ago this month that *Popular Electronics* magazine ran their “COSMAC Elf” construction project. Unlike its more famous cousin — the Altair 8800, which appeared just a year before — the Elf was a microcomputer project that anybody could afford. In the days when an 8080A chip alone cost \$300, the entire Elf could be assembled for something like \$80. That made the COSMAC Elf the first microcomputer for many experimenters, especially poor high school students like me.

And the Elf still has a place even in this century. The hardware is simple to assemble and very forgiving; the parts have pins that are easy to solder;

the timing is not critical; it only needs one simple power supply to operate; 1802 chips are still easy to find and inexpensive; and best of all, it doesn’t require billions of bytes of software to do something useful. A friend’s nine-year-old son recently put together his own Elf 2000 in a weekend and had it working before bedtime on Sunday.

This two-part series will walk you through the construction of an Elf clone using only modern, easy-to-get, parts. The Elf 2000 is true to the look and feel of the original, runs all the same software as the original, and can be used in the same way, with lights and switches. But the Elf 2000

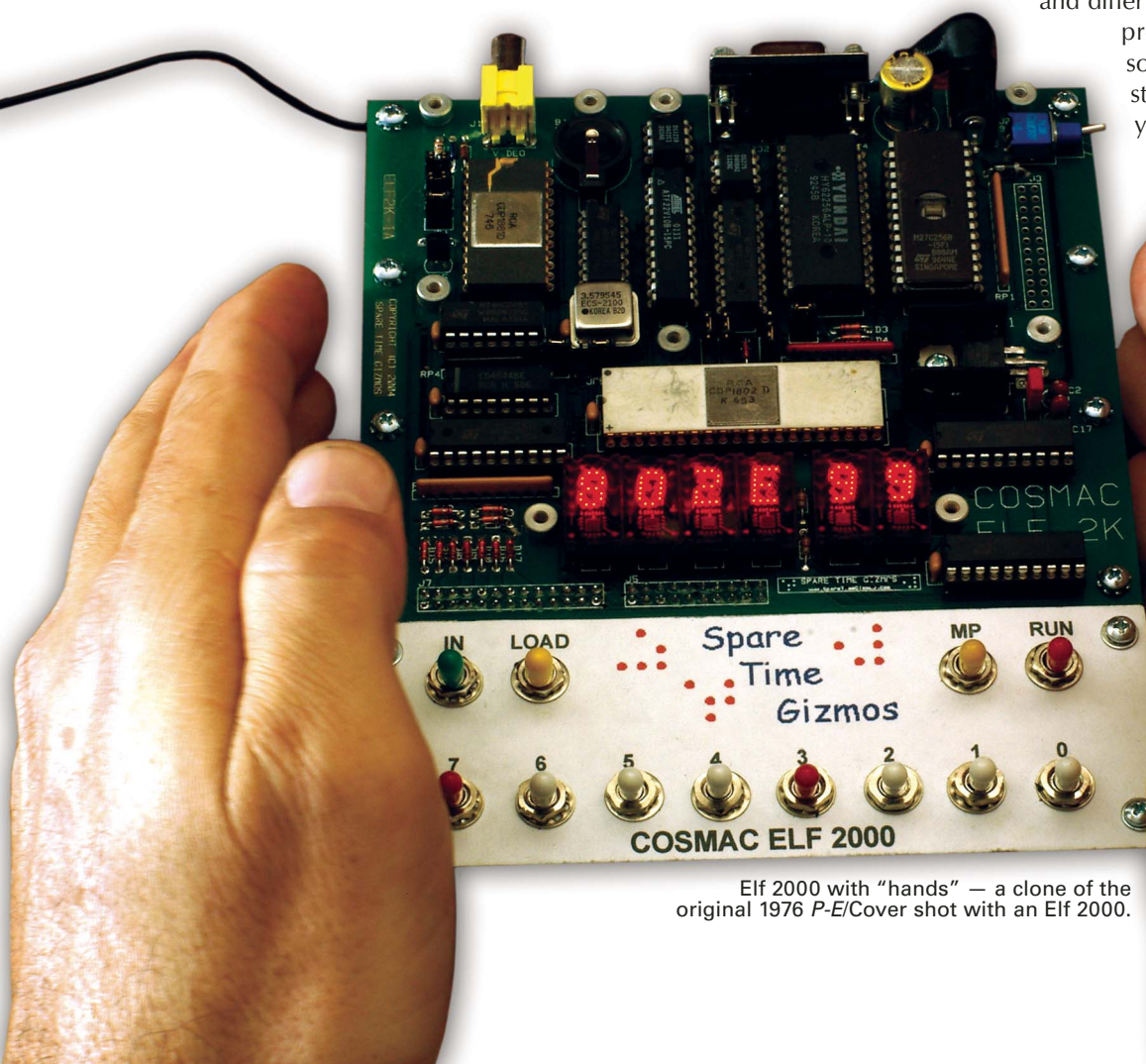
has also been updated to use slightly more modern parts outside the 1802 and fits a lot more functionality in the same space and chip count.

When you get tired of toggling in programs, you can expand it with Compact Flash mass storage, one of several video displays, and a PS/2 keyboard. There’s an impressive amount of software available for it, including Forth and Basic interpreters and an entire disk operating system, so you won’t be short on things to do.

This first part will present the complete schematic for the Elf 2000 and discuss the different subsections — how they work and how they both resemble and differ from the original. Part 2 will

present the parts list, give some hints to help with construction, and describe testing your completed Elf 2000. Part

2 will also discuss some of the software (the BIOS, languages,



Elf 2000 with “hands” — a clone of the original 1976 *P-E* Cover shot with an Elf 2000.

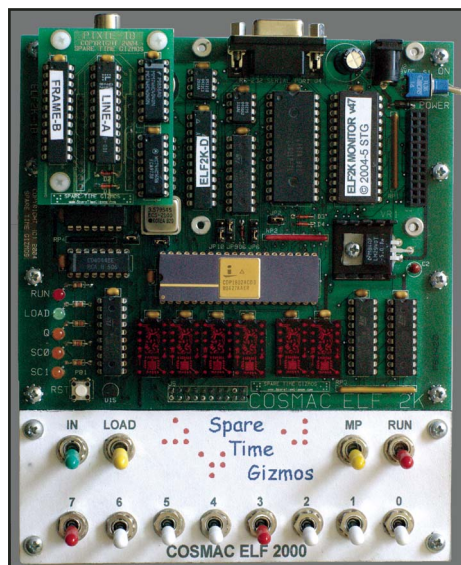


PHOTO 1. Elf 2000 board close up.

1802 — the same basic chip that’s been around since 1976. You might think that I’m cheating on my promise to use modern parts, but believe it or not, Intersil still manufactures the CDP1802. In fact, the pretty purple ceramic chip shown in Photo 1 is a brand new Intersil CDP1802ACD with a June 2004 date code.

You might not want to buy yours from Intersil, though — they’re pretty expensive new. You can find new old stock, like plastic CDP1802ACE chips on eBay for about \$10 if you’re patient, and the original ceramic RCA CDP1802CD version for a bit more. If you’re lucky enough to find a “B” version (e.g., CDP1802BCE), then grab it — these will work at 5 MHz and can be used in the Elf 2000 at almost twice the speed of the ACE or CD versions.

Memory

The original Elf had 256 bytes (not Kbytes or Mbytes — bytes!) of RAM, but it’s actually pretty hard to find 256

byte RAM chips anymore. The Elf 2000 doesn’t even bother and uses a single 32Kx8 SRAM instead. In the original Elf, the RAM contents were lost every time you turned off the power, which was a real problem after you’d just spent hours toggling in a program with the switches!

Many people added battery backup to their Elf; the Elf 2000 has battery backup provided by a Lithium coin cell and the DS1210 non-volatile RAM controller as a standard feature. Even if you don’t plan on using the toggle switches, it’s really nice to be able to type in a long Basic, Forth, or Assembly program and have it still be there the next time you turn on the Elf 2000.

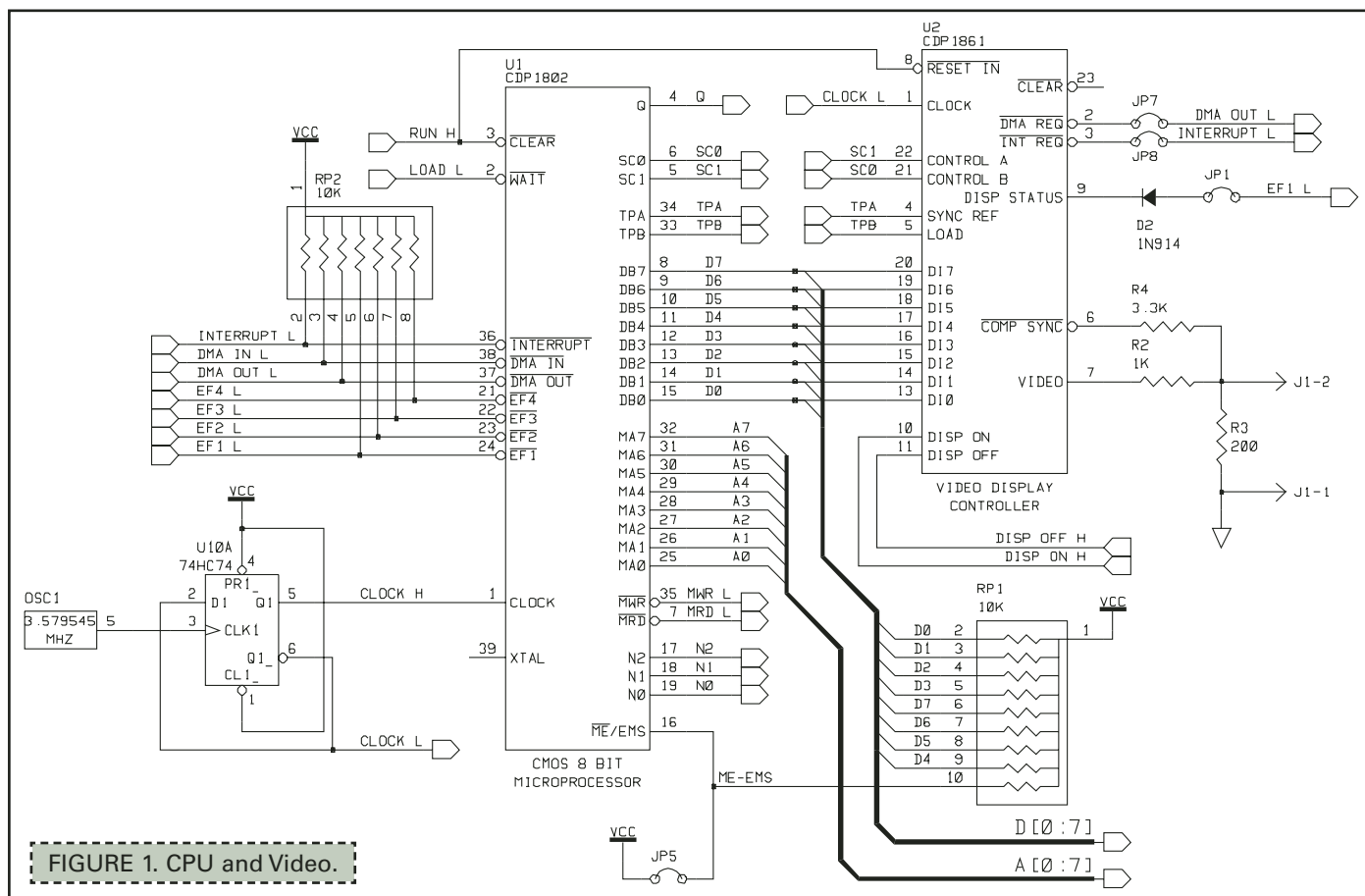
ROMs were both very expensive and very small in 1976 and the original Elf had none, but the Elf 2000 adds a 32Kx8 EPROM to fill out the address space. This EPROM contains power on self test firmware, a monitor and debugger, a bootstrap for the disk operating system, interpreters for the Basic and Forth languages, as well as a

disk operating system, and more) available for the Elf 2000 and also present some ideas for expansion.

Theory of Operation

CPU

The microprocessor used in the Elf 2000 is, of course, the venerable



simple Editor/Assembler.

The toggle switches look good and are fun to play with, but you'll find that rapidly becomes old after you've toggled in a few programs. It's much easier to download your HEX files from a PC over the serial port using the monitor firmware in the EPROM!

But if you prefer, the Elf 2000 can

control switch logic, and toggle in loader mode. In the Elf 2000, all of this logic is replaced by a single GAL22V10 programmable logic device. Don't be put off if this is your first experience with programmable logic — not only are PLDs easy to use, but the PLD gives the Elf 2000 extraordinary flexibility. Want to swap

manually reset it before doing anything, but the Elf 2000 uses a DS1233 VCC monitor to provide an automatic power on clear. And if the EPROM is installed in your Elf 2000, you might like the firmware to execute automatically after a power on clear. This can be a problem because the 1802 wants to start executing at

"In the days when an 8080A chip alone cost \$300, the entire Elf could be assembled for something like \$80. That made the COSMAC Elf the first microcomputer for many experimenters ..."

be used without the EPROM and you can still toggle in programs with the switches, just like the original.

Control Logic

The original Elf needed a handful of discrete logic chips to implement memory and I/O port decoding, the

SRAM and EPROM around in the memory map? Want to change the I/O port assignments? Want to change the behavior of a switch? Not a problem — just reprogram the GAL, and no wiring changes are necessary!

When you turned on your Elf in 1976 you had to remember to

location zero after a reset, and we need RAM mapped at that location for compatibility with the original Elf.

The solution is a simple "bootstrap" circuit on the Elf 2000, also implemented by the GAL, that tricks the 1802 into executing at address \$8,000 after a power on clear. If you

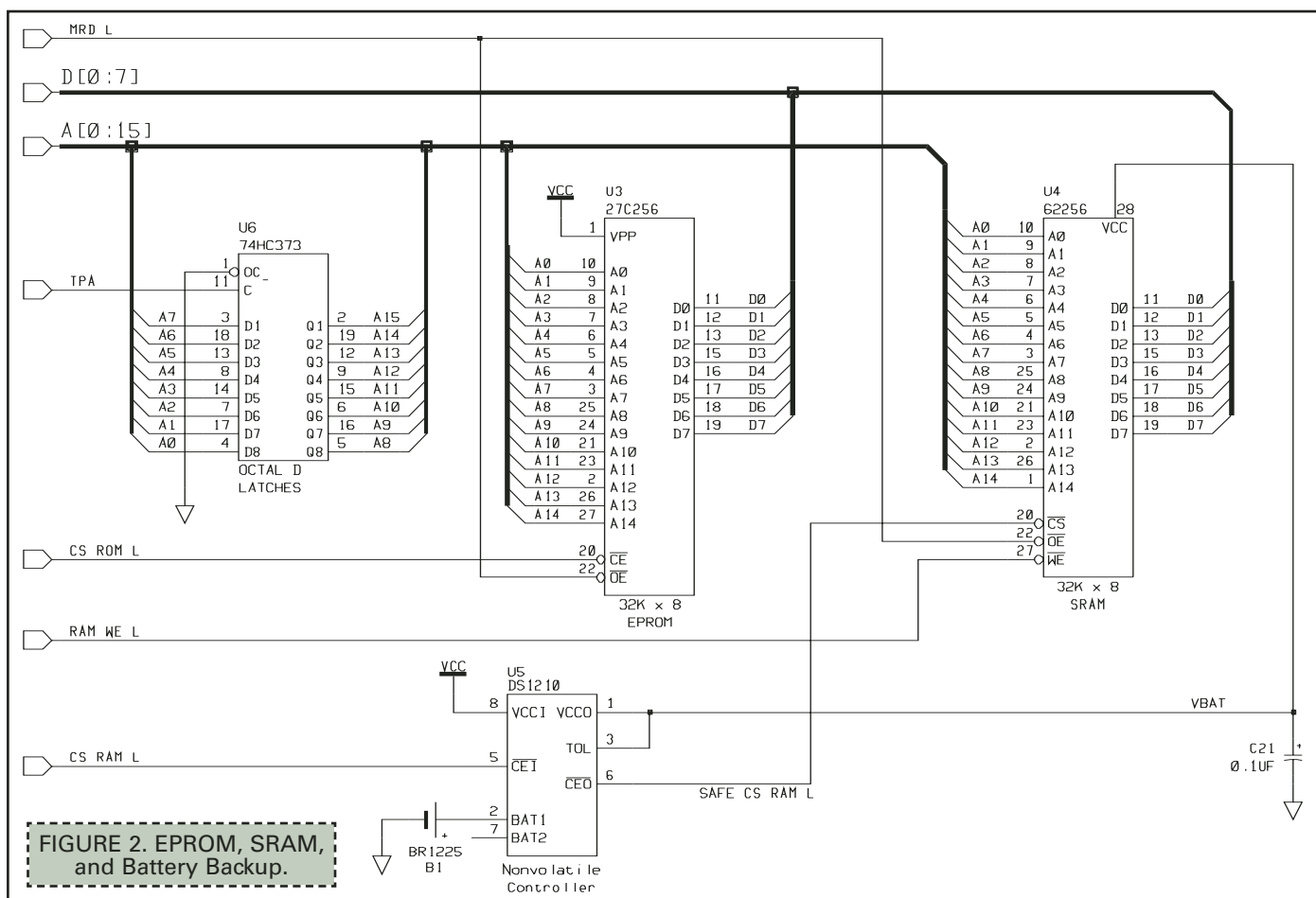
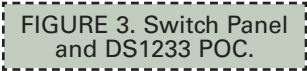


FIGURE 2. EPROM, SRAM, and Battery Backup.



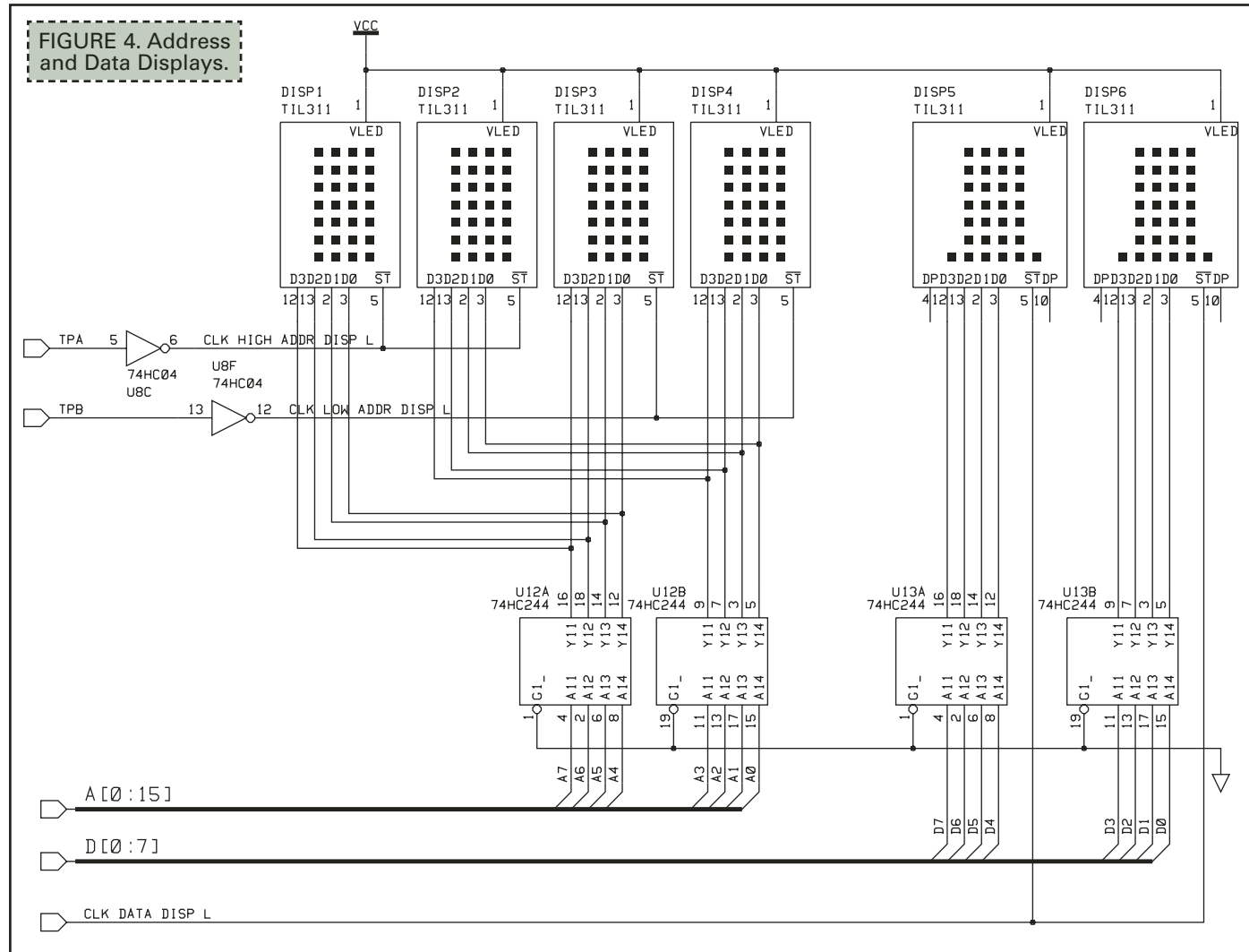
surplus stores, you can usually find them for a few dollars apiece.

Serial Port

To my knowledge, *Popular Electronics* never published a serial port addition for the original Elf, although commercial clones of the time like the Neutronics Elf II and the Quest Super Elf, had one. In 1976, the standard terminal was an ASR-33 teletype which cost a fortune and hardly any hobbyists actually had one, so there just wasn't much need for a serial port. Today everybody has one — it's called a PC, and all you need to make it work is some terminal emulation software.

The standard Elf 2000 has a “bit banged” serial port (i.e., the serial to parallel conversion is done by the

FIGURE 4. Address and Data Displays.



software) using the 1802's Q and EF3/4 I/O pins. This is the same as the interface used by the Elf II, Super Elf, and RCA 18S020 COSMAC Evaluation Board, and the Elf 2000 will run the software written for those machines. The firmware in the Elf 2000 EPROM can also use this serial port to communicate.

It's also worth noting that the Elf 2000 uses a DS275 level shifter to provide the correct RS-232 voltage levels and should work with any serial port.

Pixie Video

The original *Popular Electronics* Elf series described the construction of a "Pixie Graphics Video Display" using the CDP1861 video controller. The Elf 2000 has a socket for the CDP1861 and pretty much duplicates the same video subsystem as the original Elf. The Elf 2000 will run all the same

graphics programs, without changes, that ran on the original.

However, unlike the 1802 chip, 1861 chips haven't been manufactured for decades. They are around if you look, but finding one can be a problem and so one alternative is to use the STG1861 instead. This small daughter card, about 2" square, uses two GALs and two discrete 74HC logic chips to emulate all functions of the CDP1861, plugs directly into the same CDP1861 socket, and can be used on any Elf to replace the CDP1861. It's a testament to both the flexibility of PLDs and also the simplicity of the 1861 chip!

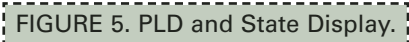
The video section is the reason behind the strange crystal frequency used in the Elf 2000 — 3.579545 MHz — and also the reason this frequency is divided by two before being used to drive the CPU. Both these are needed to generate the correct video timing.

The CDP1802ACE chip itself is good up to 2.5 MHz and, if you don't plan to use the video section, you can safely use any oscillator in the Elf 2000 up to 5 MHz.

Power Supply

The Elf 2000 is designed to use an unregulated DC supply of about 9V and the power supply used here is the exact same 7805 three-terminal linear regulator used in the original. With the TIL311 displays installed, the Elf 2000 can use 600 to 700 mA; with a 9 VDC input that means the 7805 dissipates about 3W and it will need a heatsink. Try not to exceed 9V DC for the input — in particular, don't use 12V — because you'll just increase the dissipation of the 7805.

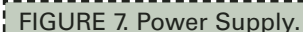
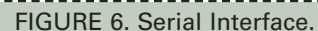
In fact, it's advantageous to reduce the input voltage to reduce the dissipation, but don't go below 8V



Until Next Month

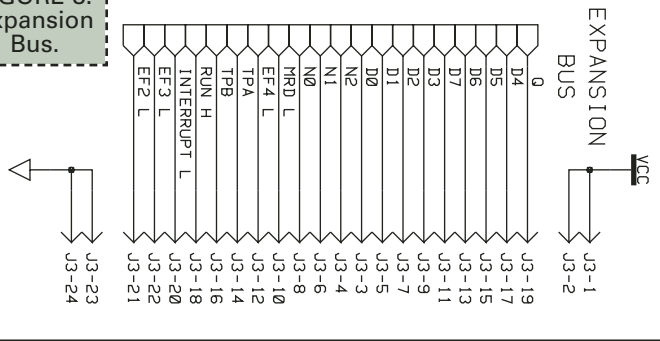
You can also join the Yahoo! COSMAC Elf group (<http://groups.yahoo.com/celf/>) and browse their messages archives. And, in there's the Spare Time group (<http://groups.yahoo.com/group/sparetimegiz>) specifically for Elf 2000 projects.

The September 2005 issue of *Circuit Cellar Ink* magazine contains an introduction to programmable logic devices and also just happens to have a description



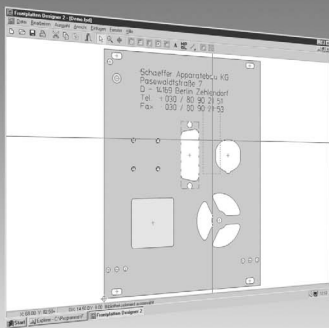
of the STG1861 replacement for the CDP1861 Pixie chip. *SERVO Magazine* has been running a bi-monthly series of articles on programmable logic starting with the March '06 issue. **NV**

FIGURE 8.
Expansion
Bus.



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■ BY PETER BEST

NOT YOUR FATHER'S TEMP/HUMIDITY MONITOR

THIS MONTH, WE'LL EXPLORE a useful application that employs the services of UDP to send detailed temperature and humidity data over an LAN in your home or through the routers and hosts that make up the Internet.

To add some spice to this project, we'll do it with a unique combination temperature/humidity sensor and Wi-Fi technology. Just in case you've ever wanted to implement a microcontroller real-time clock, we'll do that too.

Ever want to write some bit-bang code to communicate with a device external to your microcontroller? We'll do some big time bit banging in this project. And, this isn't your father's temperature/humidity monitor. Our temperature/humidity creation is accurate to within $\pm 2\%$ for humidity readings and $\pm 0.3\%$ for temperature measurements. Plus, the temperature can be displayed as degrees Celsius or degrees Fahrenheit with two digits of precision behind the decimal point.

This month also marks the beginning of **nerdvilla.com**. In addition to supplying you with the Design Cycle project printed circuit board (PCB) layout files, **www.nerdvilla.com** will provide a means for you — the *Nuts & Volts* projectors — to get professional ready-to-roll Design Cycle project printed circuit boards, complete kits of Design Cycle projects, and any of the unique parts that may accompany Design Cycle projects.

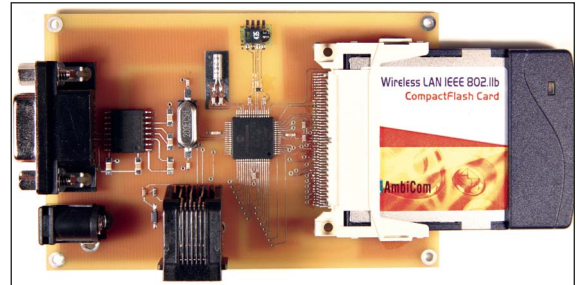
The purpose behind **www.nerdvilla.com** is to provide me a way to

help all of you get Design Cycle projects off the ground with minimal investment and minimal effort. **Nerdvilla.com** is simply a portal I am providing for you to enter and obtain Design Cycle project hardware. All of the logical and graphical Design Cycle project stuff that regularly gets put onto the *Nuts & Volts* website will still be there for you, as well.

The temperature/humidity monitor hardware behind this month's Design Cycle is shown in Photo 1. Six subsystems make up our Wi-Fi temperature/humidity monitor. The first subsystem consists of a PIC18LF6722, which is the central hub for all timekeeping, measurement, and transmission activity.

The PIC drives the second temperature/humidity monitor subsystem that happens to be a regulation RS-232 serial port built around a 3.3-volt Sipex SP3232 and associated charge pump capacitors. The third temperature/humidity monitor subsystem is found within the confines of a CompactFlash card, which houses all of the necessary electronics and logic to bring 802.11b Wi-Fi capability to the temperature/humidity monitor. A 32.768 KHz clock crystal working in conjunction with the PIC's internal TMR1 timer module forms a real-time clock, which makes

■ **PHOTO 1.** The temperature/humidity monitor uses 0603 and 0805 SMT passive components to keep the size down. If you were to leave off the CompactFlash Wi-Fi card interface and the Sensirion SHT15, this would be an every-day-run-of-the-mill microcontroller hardware design.



up the temperature/humidity monitor's fourth subsystem.

The fifth temperature/humidity monitor subsystem is represented by a six-pin RJ-11 jack. The RJ-11 jack is the portal for programming and debugging the PIC18LF6722 via the latest version of Microchip's MPLAB and MPLAB ICD2. The sixth and final subsystem is the Sensirion SHT15 itself. Instead of the normal voltage regulator circuitry, regulated power for our temperature/humidity monitor is provided by a 3.3V-DC wallwart, which is unassisted by any on-board voltage regulation circuitry.

I can extol the virtues of the temperature/humidity monitor circuitry using words but nothing can top seeing a circuit concept schematically. Thus, Schematic 1 is a graphical depiction of all of the temperature/humidity monitor's subsystems.

On the software side, the temperature/humidity monitor's source code was crafted using the HI-TECH PICC-18 C compiler. The HI-TECH source is ANSI compliant and can easily be converted to your favorite C compiler. If you don't have a PIC C compiler already, the minimum price tag for PIC C compilers is in excess of \$200 unless you can get your hands on a freebie GNU version.

Some of you have voiced your displeasure with my use of expensive development tools and I've promised those readers that I would keep my project costs down as best that I can for the good of all Design Cycle readers. So, I'll try to give you as complete of an out-of-the-box package as possible, which includes a ready-to-run compiled hex file you can load directly into your temperature/humidity monitor's PIC18LF6722.

I was talking to a NASA embedded programmer friend recently and the discussion wandered into the nuances of embedded network programming. All said and done, if a NASA programmer loathes network coding, the average programming Joe or Joan has a bit more nasty network programming water in his or her boat. So, to make things a bit easier for the Design Cycle readers, I've coded in a comprehensive networking menu routine into the temperature/humidity monitor firmware.

The temperature/humidity monitor's built-in menu allows you to

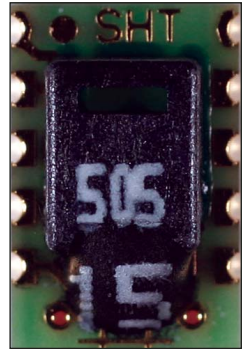
specify the intervals between measurements in seconds, the temperature/humidity monitor's IP address, the target host's IP address, and the source and destination UDP port numbers. The temperature/humidity monitor menu appears at power-up via the temperature/humidity monitor's 56K serial port. If you don't want to use the default Wi-Fi SSID of AIRDROP or you want to use WEP encryption, you'll have to make those changes in the firmware and recompile.

Now that you have a lowdown on all of the temperature/humidity monitor's subsystems and firmware, let's begin by taking a closer look at the hardware that does most all of the data collection work: the temperature/humidity sensor.

THE SENSOR

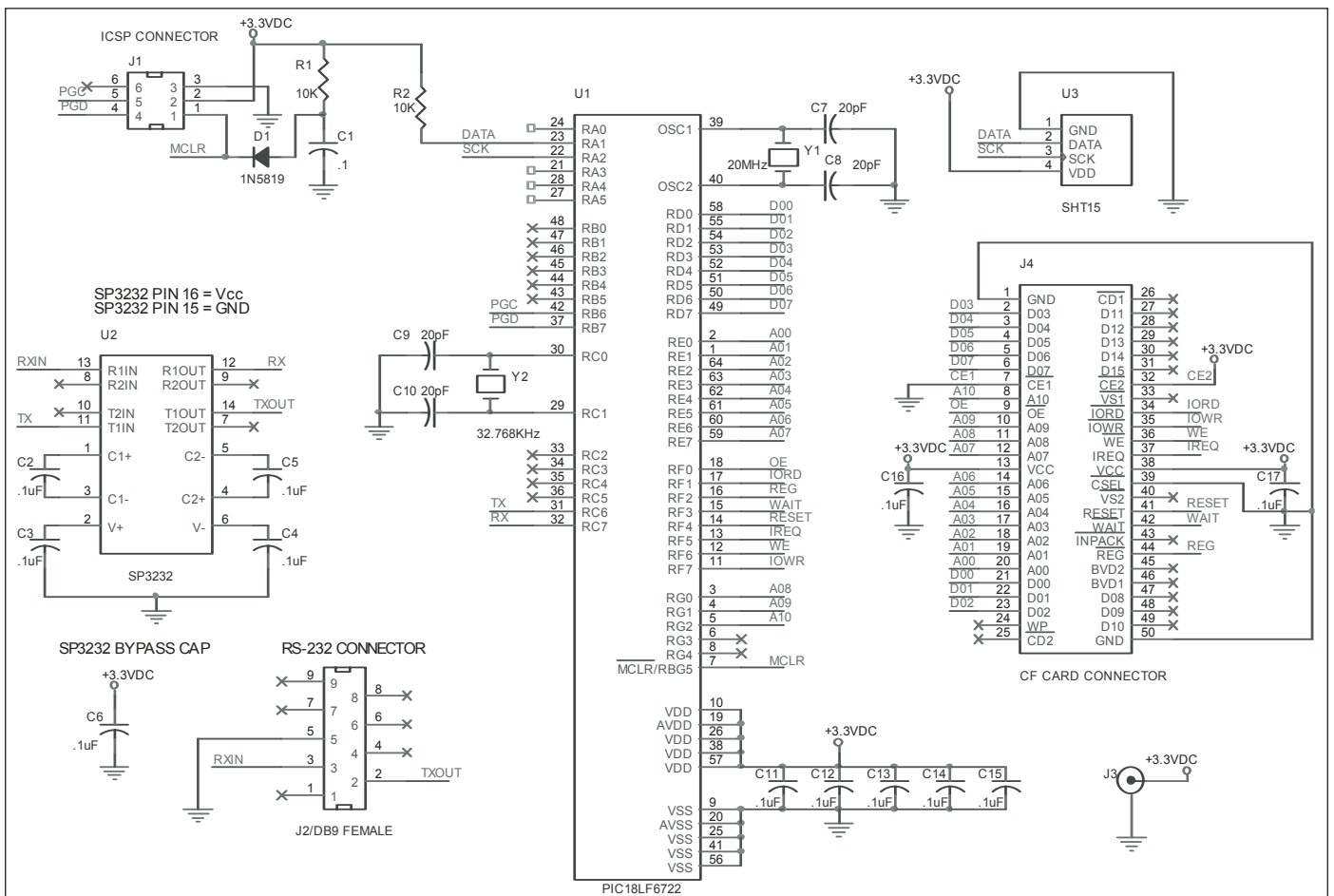
Photo 2 is a bird's eye view of a

■ **PHOTO 2.** This tiny combo sensor outputs a 14-bit temperature value and a 12-bit humidity value by default. By programming the Sensirion SHT15's Status Register, you can get eight-bit humidity readings with 12-bit temperature measurements.



Sensirion SHT15 temperature/humidity sensor, which happens to be mounted on our temperature/humidity monitor PCB. The Sensirion SHT15 comes in a dual sensor configuration, which provides a calibrated digital output. The humidity sensor component of the Sensirion

■ **SCHEMATIC 1.** Note the absence of a voltage regulator circuit. The Sensirion SHT15 is very sensitive to the heating of the printed circuit board it resides on. Eliminating the voltage regulator helps to keep the temperature/humidity monitor's printed circuit board cooler. I've also left room so you can route out the printed circuit board material around the SHT15.



SHT15 is based on a capacitive polymer sensing element.

The bandgap PTAT (Proportional To Absolute Temperature) temperature sensor component and relative humidity sensor component are connected to an on-chip 14-bit analog-to-digital converter. Temperature and humidity data are transferred via the Sensirion SHT15's on-chip two-wire serial interface.

To provide maximum stability, all of the Sensirion SHT15 sensing and communications elements are deposited on a single CMOS chip. The Sensirion SHT15's accuracy is ensured by factory-programmed calibration coefficients, which are used by the Sensirion SHT15 internally to calibrate signals from the temperature and humidity sensor elements when measurements are made.

Although Photo 2 implies that the Sensirion SHT15 is an eight-pin device, it is actually a four-pin device with pins for power, ground, data (DATA), and clock (SCK). The Sensirion SHT15 can operate within a supply voltage range of 2.4 VDC to 5.5 VDC. The Sensirion

SHT15's operation voltage does not affect the humidity calculations, but the Sensirion SHT15 supply voltage is a concern for temperature measurements.

The Sensirion SHT15 datasheet provides temperature measurement constants for use at various supply voltage levels. However, 3.3 VDC was not in the Sensirion SHT15's datasheet temperature constant table. Since the SHT15's PTAT temperature sensor's output is linear, I simply took a scientific guess and chose a logical constant value between the 3.0 VDC and 3.5 VDC values listed in the temperature constant table to use in my temperature calculations.

The terms two-wire, DATA, and SCK are synonymous with I²C. However, the Royal Philips invention is not used by the Sensirion SHT15. The

Sensirion SHT15 uses a proprietary bit-bang approach to deliver its data. Fortunately, the Sensirion SHT15 datasheet lays out the bit-bang sequences in detail and the sensor's bit-bang waveforms are easy to formulate in code. The SCK signal is used to synchronize the data transfers between the SHT15 and the PIC18LF6722. Warp speeds at the microcontroller end are not necessary as the SHT15 has no minimum SCK frequency.

The transfer of data via the Sensirion SHT15's DATA line is SCK level dependent. Data on the SHT15's DATA pin changes after the falling edge of SCK and is valid on the rising edge of SCK. Data on the SHT15 DATA pin must remain stable while SCK is high. As the Sensirion SHT15's DATA pin is bidirectional, the PIC18LF6722 only drives the DATA

LISTING 1:

This is fairly straightforward. We are simply bit-banging the transmission start sequence that is depicted graphically at the code's header. Since I had no need for speed, I used 1 mS delays.

```
//-----
void sht_xmit_start(void)
//-----
// generates a transmission start
//
// DATA:  _____|_____
//
// SCK :  ____|____|____|____
{
    TO_SENSOR;
    DATA=1;
    SCK=0;
    delay_ms(1);
    SCK=1;
    delay_ms(1);
    DATA=0;
    delay_ms(1);
    SCK=0;
    delay_ms(1);
    SCK=1;
    delay_ms(1);
    DATA=1;
    delay_ms(1);
    SCK=0;
    delay_ms(1);
}
```

LISTING 2:

I used the seconds value from the real-time clock to set up the timeout period for the SHT15 measurement cycle. Don't worry about the variables you don't see in this listing. I'll supply the entire complement of C source code on the *Nuts & Volts* website.

```
//-----
char sht_measure(unsigned int *p_value, char *p_checksum, char mode)
//-----
// takes a measurement (humidity/temperature) with checksum
{
    unsigned int i;
    char timer;

    error=0;

    sht_xmit_start();
    switch(mode){
        case TEMP:
            printf("\r\nMeasuring Temperature..");
            error+=sht_write_byte(MEASURE_TEMP);
            break;
        case HUMI:
            printf("\r\nMeasuring Humidity..");
            error+=sht_write_byte(MEASURE_HUMI);
            break;
        default:
            break;
    }
    timer = secs;
    timer +=2;
    do{
        ++i;
    }while(DATA_IN == 1 && secs < timer);

    if(DATA_IN)
        error+=1;
    hi_byte = sht_read_byte(ACK);
    lo_byte = sht_read_byte(ACK);
    *p_checksum =sht_read_byte(noACK);
    *p_value = makel6(hi_byte,lo_byte);
    return error;
}
```


pin low. A 10K pullup resistor is placed on the SHT15 DATA pin to pull the SHT15's DATA pin high.

BIT-BANGING THE SENSIRION SHT15

There are only five commands that can be executed by the SHT15: Measure Temperature (binary 00011), Measure Humidity (binary 00101), Read Status Register (binary 00111), Write Status Register (binary 00110), and Soft Reset (binary 11110). An address sequence of binary 000 is attached to the beginning of each command to form an eight-bit command. Each eight-bit command sequence is preceded by a transmission start sequence.

A transmission start sequence lowers the DATA line while the SCK line is high. The DATA line remains low as the SCK line is taken low and then high. The SCK remains high and the DATA line is brought to a high level. A graphic depiction of what I just said and the code to make a transmission start happen can be seen in Listing 1.

To acknowledge the receipt of a proper transmission start/command sequence, the SHT15 pulls the DATA line low after the falling edge of the eighth SCK pulse. This is called an ACK bit in the Sensirion SHT15 datasheet. The SHT15 releases the DATA line after the falling edge of the ninth SCK pulse. The 10K pullup resistor on the DATA line insures that the DATA line will go high as the PIC18LF6722 DATA line is in input mode and does not drive the DATA line at this time.

Let's assume that a Measure Temperature command has been issued. Following the issuance of the Measure Temperature command, the PIC18LF6722 sees the Sensirion SHT15 release the DATA line to assume a high level and takes this action as a signal that the measurement cycle has begun. Some 210 mS or so later, the measurement cycle completes and the SHT15 pulls the DATA line low. The dropping of the DATA line by the SHT15 indicates a data ready condition. The SHT15 stores the data until the PIC18LF6722

desires to retrieve it. The most recent data won't be overwritten unless a new measurement cycle is invoked.

When the PIC18LF6722 decides to retrieve the measurement, the SHT15 formats the measurement data into a pair of bytes followed by a byte of CRC checksum. The PIC18LF6722 clocks out the measurement data most significant bit first and right justified. Each byte that is clocked out by the PIC18LF6722 is acknowledged by the PIC18LF6722 pulling the DATA line low. The measurement retrieval cycle ends after the acknowledgement of the CRC byte, which is optionally retrieved, and the SHT15 automatically falls back into sleep mode. This entire temperature and humidity measurement process is translated into C source code in Listing 2.

Just in case the SHT15's serial interface goes into LA-LA land, a connection reset sequence can be bit-banged to the SHT15 to reset it.

The connection reset sequence is simply nine or more SCK pulses followed by a transmission start sequence. The connection reset code is in the download source code package.

I also wrote some SHT15 Status Register read/write routines, which are in the source package, but I didn't have to touch the Status Register for this application and they were never called.

Okay, now you have all of the code you need to take temperature and humidity measurements with the Sensirion SHT15. You also have code to reset and interrogate the SHT15's Status Register. Let's move on and look at the code that will put the measurements into a UDP datagram.

ENCAPSULATING THE SENSIRION SHT15 MEASUREMENT DATA

The Wi-Fi code used in our tem-

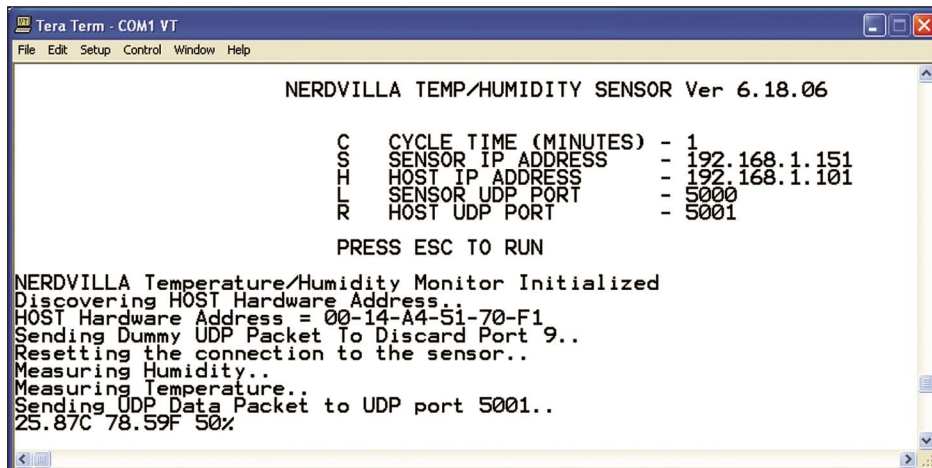
LISTING 3:

This listing is heavily abbreviated. Lots of Wi-Fi things are also taking place within this piece of code in addition to calculating human-readable temperature and humidity values that are sent out on the temperature/humidity monitor's serial port.

```
void main(void)
{
    unsigned int i,temp,evstat_data;
    char rc,timer;

    printf("\r\nDiscovering HOST Hardware Address..");
    clr_arpflag;
    do{
        rc = arp_request();
        do{
            evstat_data = rd_cf_iol6(EvStat_Register);
        }while(!(evstat_data & EvStat_Rx_Bit_Mask));
        get_frame();
    }while(barpflag == 0);
    printf("\r\nHOST Hardware Address = %02X-%02X-%02X-%02X-%02X",
    remotemacaddrc[0],remotemacaddrc[1],remotemacaddrc[2],
    remotemacaddrc[3],remotemacaddrc[4],remotemacaddrc[5]);
    delay_ms(100);
    init_udp();

    while(1){
        if(mins == parameters[loopsecs])
        {
            send_udp_discard(); //discard udp port
            delay_ms(100);
            send_udp();
            mins = 0x00;
        }
        do{
            evstat_data = rd_cf_iol6(EvStat_Register);
        }while(!(evstat_data & EvStat_Rx_Bit_Mask));
        get_frame();
    }
}
```



■ PHOTO 3. This is a shot of the menu function that runs each time the temperature/humidity monitor is powered up or reset. The data entered by the user is stored in the PIC18LF6722's integral EEPROM.

perature/humidity monitor is based on the EDTP AirDrop-P. The Airdrop-P driver and application code is fully documented in a book written by Fred Eady called *Implementing 802.11 with Microcontrollers*. There is also a Yahoo! AirDrop forum that contains a wealth of information about the AirDrop-P

hardware and firmware. All of the EDTP AirDrop-P driver routines are included in the temperature/humidity monitor source code download package that is available on the *Nuts & Volts* website (www.nutsvolts.com).

In other words, we won't get deep into the mechanics of the Wi-Fi

code. However, you do have multiple paths of full access to the inner workings of the Wi-Fi code if you choose to explore them.

Listing 3 is a code snippet of the C main() function. Everything up to this point within the main() function is initialization oriented, as I have set up and kicked off the real-time clock, initialized the PIC18LF6722 USART, asked for your desired network parameters via the menu function, and initialized the Wi-Fi CompactFlash card. We're now at the point at which we need to find out some things about the host that is going to receive our temperature/humidity-laden UDP datagrams. The arp_request() function

is the vehicle we will ride to obtain the remote host's MAC (hardware) address.

We haven't talked much about ARP and I've promised to cover all of the essential Internet protocols over time in Design Cycle columns. Now is as good a time as any to talk about ARP. Address Resolution Protocol (ARP) is used to obtain an unknown host MAC address that is associated with a known IP address. Before any two hosts can communicate, they both must know the other's IP and MAC addresses.

For now, ignore everything below "PRESS ESC TO RUN" in Photo 3, which is a screen shot of the menu() function in action.

LISTING 4:

```
//*****
/**  send_udp
/**  This function sends UDP data
//*****
char send_udp(void)
{
    unsigned int TxFID;
    char rc,timer,temp[2];

    timer = secs;
    timer += 10;
    do{
        sht_connectionreset();
        error=0;
        error+=sht_measure(&humi_val,&humi_chksum,HUMI); //measure humidity
        error+=sht_measure(&temp_val,&temp_chksum,TEMP); //measure temperature
    }while (error!=0 && secs < timer);

    udp_packet[UDP_data] = temp_val;
    udp_packet[UDP_data+1] = make16(0x00,temp_chksum);
    udp_packet[UDP_data+2] = humi_val;
    udp_packet[UDP_data+3] = make16(0x00,humi_chksum);

    printf("\r\nSending UDP Data Packet to UDP port %d.\r\n",make16(temp[1],temp[0]));
    rh_lin = C3 * humi_val * humi_val + C2 * humi_val + C1;
    rh_true = ((temp_val*0.01) - 39.63) * (T1+T2*humi_val) + rh_lin;
    if(rh_true > 100)
        rh_true = 100;
    if(rh_true < 0.1)
        rh_true = 0.1;
    printf("%3.2fC %3.2fF %d%\r\n", (temp_val*0.01) - 39.63, (temp_val*0.018) - 39.31, rh_true);

    do_event_housekeeping();
    return(rc);
}
```


The network-centric data in the menu area of Photo 3 represents known data that the temperature/humidity monitor user/programmer has entered. The measurements will occur every 60 seconds, the temperature/humidity monitor IP address is 192.168.1.151, the remote host IP address is 192.168.1.101, the temperature/humidity monitor's UDP port address is 5000, and the remote host's UDP port is addressed as 5001.

The `arp_request()` function sends a broadcast message in the form of an ARP request, which presents both the sender's IP and MAC addresses to everyone in a position to receive the ARP request message. The host with an IP address of 192.168.1.101 will respond to the ARP request and include its MAC address in the response.

Now, go below the "PRESS ESC TO RUN" message to see the results of the temperature/humidity monitor's ARP request message. The HOST Hardware Address that was returned happens to be a laptop on the LAN with the temperature/humidity monitor. Note that IP addresses beginning with 192 cannot be routed on the Internet and are relegated to use in localized private networks. So, you can conclude that the temperature/humidity and the laptop are on a private local LAN.

If Internet access is needed from a private LAN that uses a non-routable IP address, both the laptop and the temperature/humidity monitor have the option of accessing the Internet via a NAT (Network Address Translation) gateway device.

With all of the necessary information to assemble a UDP datagram in hand, the `init_udp()` function builds a UDP datagram skeleton in the PIC18LF6722 SRAM. Blanks within the UDP datagram skeleton are filled in by code running in the `send_udp()` function.

The actual temperature and humidity measurement values are sent within the UDP datagram as raw binary values, which were taken directly from the Sensirion SHT15. I've taken the liberty to convert the binary measurements to human-readable ASCII messages in the `send_udp()`

function and display the measurement data via the temperature/humidity monitor's serial port.

CLOCKING OUT

When you've had the chance to examine the temperature/humidity monitor code closely, you'll notice that I used the real-time clock a bunch to set deadlines and trigger events. The real-time clock code is very simple to implement as the tough stuff is done in hardware. All I had to do was attach a 32.768 kHz clock crystal to the PIC18LF6722's T1OSI and T1OXO crystal oscillator pins, load up TMR1 to overflow every second, and catch the overflows with an interrupt service routine.

For those of you wondering how you're going to retrieve the data from the UDP datagram, fret not. The *Nuts & Volts* source code download package includes a little Visual Basic program that pulls the data from the incoming UDP datagram. The Visual Basic UDP application then uses the raw measurement data to calculate and show the temperature and humidity data in human-readable form.

For those of you that want to build your own temperature/humidity monitor from scratch, the *Nuts & Volts* download package also includes the

SOURCES

■ **Mouser** — Sensirion SHT15
www.mouser.com

■ **Wi-Fi temperature/humidity monitor parts and pieces**
www.nerdvilla.com

■ **HI-TECH Software** — HI-TECH PICC-18 C compiler
www.htsoft.com

■ **Microchip** — PIC18LF6722
www.microchip.com

ExpressPCB printed circuit board CAD file. You can use the temperature/humidity monitor ExpressPCB CAD file as-is or modify it to suit your needs.

If you're rusty on UDP, just check out the Design Cycle column in which UDP was the theme. I'm always available to you via email (peterbest@cfl.rr.com). So, feel free to contact me with any questions or comments concerning embedded UDP network programming. After all, it's my job to help you weave embedded UDP programming techniques into your Design Cycle. **NV**

ABOUT THE AUTHOR

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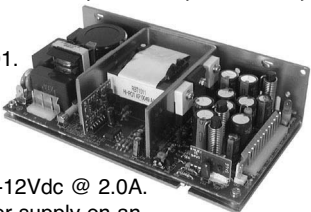
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what buttons are pushed and for how long and

depending on which leds are lighted, the relay

may or may not switch. We supply a basic

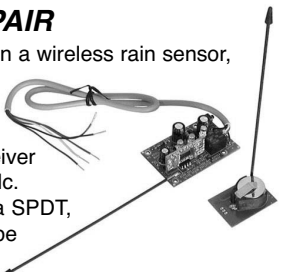
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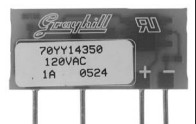
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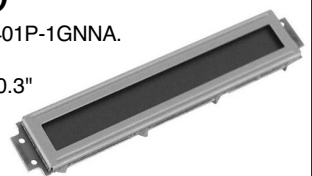
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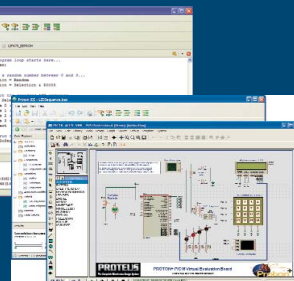
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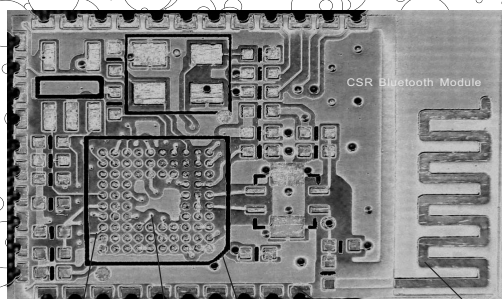
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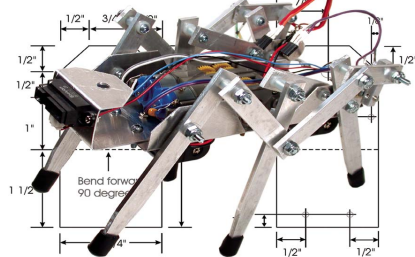
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■ BY PHIL DAVIS

DESIGN A MINI SUMO — PART 2

FOR THOSE JUST JOINING or the uninitiated, a Mini Sumo Robot and Mini Sumo competitions take their name from the Japanese form of wrestling called Sumo. In this case, two robots (smaller than 4 x 4 inches) combat in a black ring just over 30 inches in diameter, bounded by a one-inch border. For three minutes, each robot attempts to locate the other and push it off the edge.

Last month, we went over mechanical design of a Mini Sumo robot. This month, I would like to discuss the software that makes it all work, but first, a few words about the CPU board that I used on the bot.

As I mentioned, for the Mini Sumo event our robotics club sponsored, we standardized on a small CPU board we call the “Brandon Board” after Brandon, a club member who designed it and basically built 15 of them for us.

THE CPU BOARD

This board is built around an Atmel Mega32 — an eight-bit RISC processor of which the PWM lines drive a TI SN754410 1A dual H-bridge. And that is pretty much it, along with a bunch of the I/O lines surfaced in the form of pin headers, allowing for the easy connection of sensors and switches (see Figure 1). Brandon also provided a JTAG interface for this board, which simplified the download and debugging process.

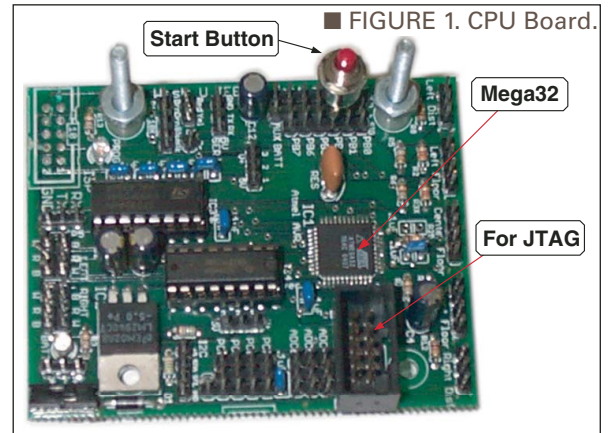
THE DEVELOPMENT ENVIRONMENT

So ... we have the mechanical

platform, motors, wheels, and a CPU board. What’s next? Well, we need some mechanism to write programs and another mechanism (if not the same one) to download the programs into the CPU board. Here we get to use my favorite word again ... FREE! Yep, free for both the compiler and the downloader; can’t beat that for the hobbyist budget!

I choose to write the code for the Mini Sumo in ‘C’ — a rather straightforward language which allows you to get down and dirty and close to the hardware when necessary. The free C compiler System is WinAVR which includes the GNU GCC compiler and may be downloaded from <http://winavr.sourceforge.net/> This system comes with a Programmer’s Notepad (an editor for writing your C code), a Wizard for generating your own custom makefile (used to compile), and some other useful bits and pieces including a pre-built library (AVR Lib with source code) to make programming the Atmel parts easier.

The FREE application which allows you to download and debug your application is AVRstudio from Atmel and can be downloaded from www.atmel.com/dyn/products/tools_card.asp?tool_id=2725



These are two excellent systems which work together very well to provide a complete software development environment for the Atmel processors. Without going into a lot of detail, there are two ways you can use this development system.

One way is to develop all your code using the Winavr Programmer’s Notepad, compile using a Makefile, then use AVRstudio to download the object (hex file) and debug. The other way is to use AVRstudio as the editor/development environment, as well as the downloader and debugger. You can do this with the aid of a plug-in called avrgccplug-in. Both ways work, so it’s really just a matter of personal preference.

PROGRAMMING THE APP

At last! We are in a position to write some code and get our bot moving, but first, a slight diversion. The conventional programming wisdom of a microprocessor this size suggests we do it with Basic, or in our case C, and that we write the code directly on top of the architecture of the chip.

At first glance, this appears to be a simple and easy way to program your app and, to be honest, it is (at

first). All is well if you are writing a fairly non-complex app such as blinking some LEDs, driving around in circles, etc., but once you get into a more complex application where many things are potentially happening at the same time, then things get a little screwy. This is because there is no facility in these languages (nor should there be) to monitor or do many things at the same time, or at least give the appearance of doing so.

Consequently, we typically fall back to writing some form of case statement or loop to perform all the necessary tasks one right after the other and therein lies the problem. We do these things one right after the other, in a serial fashion. In our Mini Sumo example, this is not good if we are in “attack mode” and we run across the line without being able to get back around the loop to check the sensors. I know this is a rather obtuse example but nevertheless, it is difficult to write code like this in a serial fashion and it often ends up resembling spaghetti.

So what is the solution? Most computers you are familiar with today have an operating system, for example MS Windows, which handles all the housekeeping required and gives us the impression that many things are happening at the same time.

FREERTOS

So, why not put an operating system on our Mega32 with its 32K of Flash memory and 2K of SRAM? Exactly! Why not? Sometime ago, I found an excellent operating system ideal for this purpose — FreeRTOS. There are two important words joined together here. The first is ‘free’ (yes, this operating system will cost you not a penny) and the second word is ‘RTOS’ which stands for Real Time Operating System. This terrific little operating system is perfectly sized to fit inside the Mega32 or even a smaller chip such as the Mega16 and may be obtained from www.freertos.org/

FreeRTOS provides us with several sets of much-needed functionality:

- The ability to split our application into separate independent tasks.
- The ability to prioritize these tasks.
- The requirement that the highest priority available task runs (Pre-emptive Multitasking).
- The ability to pass messages between tasks.

THE MINI SUMO APPLICATION

With the aid of FreeRTOS, we are no longer constricted to writing serial code. We can divide our application up into separate independent tasks and FreeRTOS will give us the illusion that each of these tasks is running at the same time. It does this by rapidly switching between tasks (giving each one a small amount of time to run — a tick), making sure that if a higher priority task is ready to run, it will

stop the current task and start the higher priority task. This is the part which is called Pre-emptive Multitasking.

Before proceeding further, we should think a bit about those functions which are important for a Mini Sumo robot to have and their associated priority. For example, these might be:

- Don’t fall out of the ring.
- Find the opponent.
- Push the opponent out of the ring.

And they should happen in that order of priority.

We can now design our application by breaking these basic functions into separate tasks. As you can see from Figure 2, I have broken the app into about 10 separate tasks.

Hopefully, without going into a lot of detail,

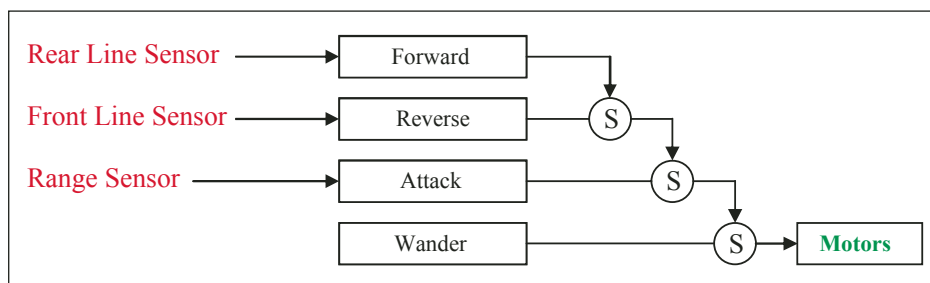
the function behind each task is understandable. The first two tasks — Wait_For_Start and Start_Strategy — only exist long enough for the operator to press the start button and for Start_Strategy to move the bot out of the way of an immediate attack and to get all the other tasks running. After that, they are deleted, which frees up some memory. This leaves us with all the other independent tasks running.

Note that all of these tasks are running concurrently (or giving the illusion thereof), allowing us to concentrate on various strategies of attack and defense, all the while in the background we have a set of tasks running which are checking the sensors. This approach of using FreeRTOS gives us the ability to program much more complex behaviors than might be possible with using a language ‘only’ on top of the chip.

All is fine but, so far, there is little organization to all of these tasks. This

■ FIGURE 2. Independent Mini Sumo Tasks.





■ FIGURE 3. Mini Sumo Subsumption Architecture.

with the tasks.

One of the beauties of the subsumption architecture is that it is easily extensible. In essence, the way I designed this was to create the “wander” task first. I then sat the bot on a table and watched it randomly move around. Of course, I had to catch it before it fell off the edge, and had there been a white line, it would have been completely ignored. I then created `Sense_Forward_Line` and the `Avoid_FLine_Strategy`. Now when I placed the bot in a Mini Sumo ring, it wandered around and if the front sensors were hit, it backed up.

So you can see, without having to go back and modify the code, I was able to add additional tasks and build upon the functionality of the bot. This is even more clear as you begin to add higher level strategies, such as different or modified attack strategies or perhaps an avoidance strategy so your opponent can never touch you. (That’ll frustrate them!)

Before wrapping up, I want to spend a few minutes talking about the actual implementation of the subsumption architecture. These behaviors or strategies as I’ve called them are typically coded in terms of Finite State Automata. Subsumption actually uses a modified FSA to allow for behaviors to execute across time. Figure 4 is an example in pseudo code of how the `Avoid_FLine_Strategy` might work. Here you can see that the execution of this strategy takes as much as a second to complete. Because this particular bot did not have encoders on the wheels, precise movements could not be made, so turns and distances traveled were estimated by turning on the motors and going to sleep for some interval.

Typically, in an implementation of subsumption, there would be an Arbiter which would prioritize tasks and resolve any conflicts between tasks of equal priority. I have an Arbiter task but, in this case, I mostly

■ FIGURE 4. Pseudo code for Avoid Forward Line Strategy.

is where a very nifty structure for programming robots called Subsumption Architecture fits in.

SUBSUMPTION ARCHITECTURE

Around 1986, Rodney Brooks — who heads up the AI department at MIT — came up with this novel concept or model for programming what we might think of as simple and reactive tasks — the Subsumption Architecture. Subsumption means that behaviors at lower levels are

subsumed by those at higher levels; higher being a higher priority or a more pressing need. In the case of the Mini Sumo task set, the highest priority task is “Don’t fall out of the ring” which is triggered by the front or rear sensors detecting the white line. No matter what else might be going on at the time, the behavior to prevent us from falling out of the ring must take over when needed.

Using this architecture, we can now layer a level of organization over the Mini Sumo tasks we have created. Looking at Figure 3, you can see that it correlates almost exactly

```
void Avoid_FLine_Strategy() {
    Strategy_Finished = FALSE;
    for( ;; ) {
        switch (Strat_State) {
            case STRAT_START:
                Led(ON); // Turn on the LED
                Strat_State = STRAT_TURN; // Set next State
                break;
            case STRAT_TURN:
                if (Left_Front_Sensor)
                    Turn(REV, CW); // Left sensor triggered
                else
                    Turn(REV, CCW); // Right sensor triggered
                TaskDelay(.2 seconds); // Sleep and let other tasks run
                Strat_State = STRAT_BACKUP;
                break;
            case STRAT_BACKUP:
                MoveStraight(REV); // Reverse
                TaskDelay(.5 seconds); // Sleep and let other tasks run
                Strat_State = STRAT_ROTATE;
                break;
            case STRAT_ROTATE:
                Rotate(CCW); // Rotate
                TaskDelay(.3); // Sleep and let other tasks run
                Strat_State = STRAT_END;
                break;
            case STRAT_END:
                Led(OFF); // Turn Off LED
                Stop(); // Stop motors
                Strategy_Finished = TRUE; // Let Arbiter know we are finished
                Clear_Forward_Sensors(); // Clear forward sensor and unlatch
                break;
            default:
                break;
        }
    }
}
```


RESOURCES

■ WinAVR

<http://winavr.sourceforge.net/>

■ AVRstudio

www.atmel.com/dyn/products/tools_card.asp?tool_id=2725

■ FreeRTOS

www.freertos.org/

■ *Mobile Robots* by Joseph L. Jones and Anita M. Flynn.
Rodney Brooks, MIT.

relied on the inherent prioritization mechanism of FreeRTOS to schedule tasks accordingly. However, my Arbiter does set and reset various states of the various tasks and acts as an 'exec' or control of the various strategies.

Hopefully, while reading this overview, you are not too confused. I understand there is a lot going on here:

- The Mega32
- The programming environment
 - AVRstudio
 - WinAVR
- FreeRTOS as an Operating System
- Subsumption architecture
- And finally, the Mini Sumo app

However, if you do make the time to take this approach, you will be richly rewarded with a 'system' which will allow you to easily construct complex behaviors and which may be extended as required. You can keep this as a base architecture for all of your future robots and build on it as needed. **NV**

ABOUT THE AUTHOR

■ *Phil Davis has a computer science degree from British University and was a member of the Royal British Computer Society. Comfortable both with software and mechanics, he is passionate about doing things that have not been done (much) before. He can be reached at phild2@charter.net*

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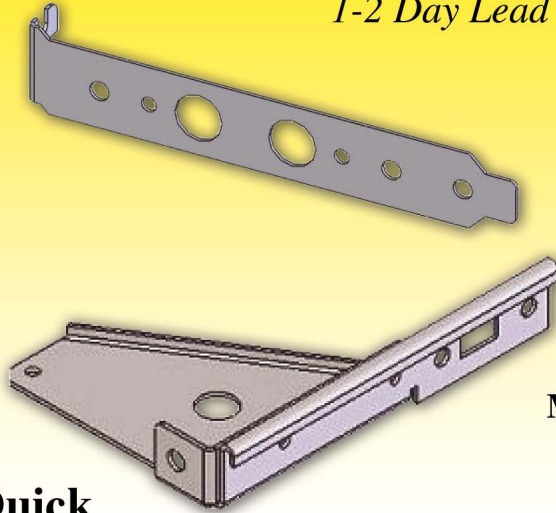
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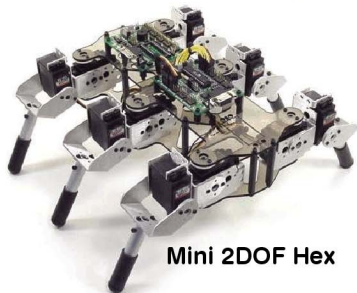
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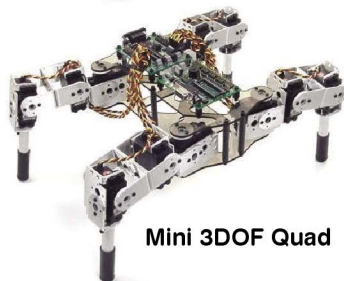
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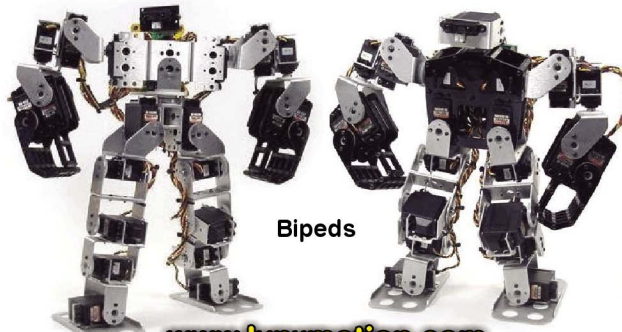
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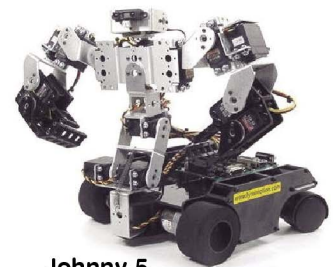
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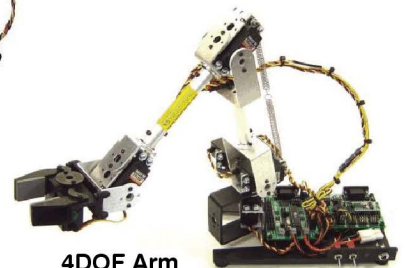
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■ BY CHUCK HELLEBUYCK

MULTIPLEXED LED DISPLAYS AND RELAYS

FEEDBACK IS IN AND READERS HAVE MADE IT CLEAR they like the information presented in previous articles but now they want more projects. I cannot blame them at all, but in-depth projects take more time than I typically have between articles so I intend to do simple but useful projects with PICs that can easily be expanded on.

For this article, I wanted to demonstrate how to control two LED displays from one set of I/O pins in a method called multiplexing. To make this into a project for the reader, I revisited a model rocket launch control box design I did back in high school (long time ago) for an electronics competition. I've seen similar type projects in *Nuts & Volts* so I was bit reluctant to cover another rocket launcher, but it was such a great example of how using PICs and the Basic language can simplify a design, I could

not resist. Besides, I took it in a new direction to demonstrate multiplexing and also introduce how to drive a relay from a PIC pin using a simple transistor buffer interface. Let's get started.

The original "high school" design shown in Figure 1 was built around TTL chips and the tripping circuit involved an SCR (Silicon Control Rectifier).

Figure 2 shows the guts of the original design with all the chips and circuitry required to do this before micro's were available to the hobbyist. I obviously had stolen some of the chips because some of the sockets are empty.

The reason I picked a relay over the SCR was to show how a PIC-based design can easily control things other than a rocket. A Christmas display or fireworks display could be built from modifications to this design. Adding another digit to the display would have taken at least two more chips with the original method. By using multiplexing and software, I still can do it with one PIC. The design doesn't need a lot of I/O or memory, but I'm sticking with the PIC16F876A because it works fine and many readers now have at least one on their bench.



■ FIGURE 1

PROJECT DESCRIPTION

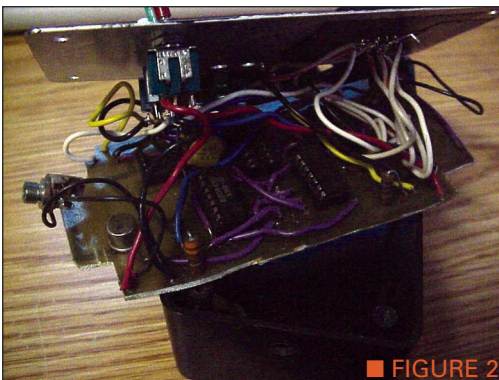
The original design operation used a single LED display to count down from 9 to 0 and then fired the SCR to route current to the igniter that ultimately fired the Estes rocket engine. The actual module doesn't work anymore, so I'm trying to remember everything it did from memory. The front plate has a run/hold switch, an on/off switch, and a safe/fire switch. It originally had a power on LED and continuity LED along with the seven segment LED display. The launcher had a continuity check mode which is something I didn't have time to include in this design. It also had a means to pause the countdown which I also didn't have time to complete. I purposely used the momentary switch on B0 so I could create an interrupt which we covered in the June column. Therefore, I've left plenty of "next step" topics for the reader. Besides, the multiplex LEDs and relay were the messages I wanted to get out. With this background, let's review the new design.

PIC DESIGN

I decided to drive the two seven-segment LED displays to count down

NOTE:

■ The complete software listing is available on the *Nuts & Volts* website at www.nutsvolts.com



■ FIGURE 2

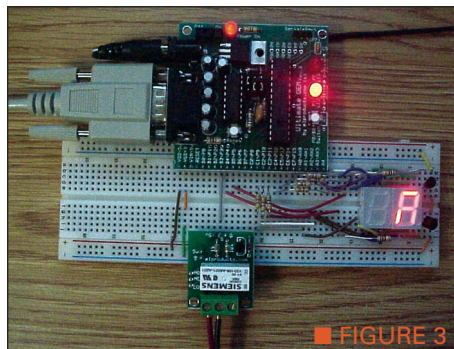


FIGURE 3

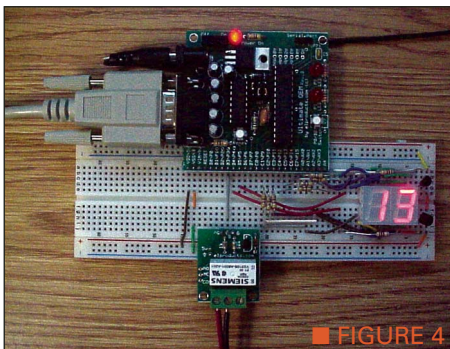


FIGURE 4

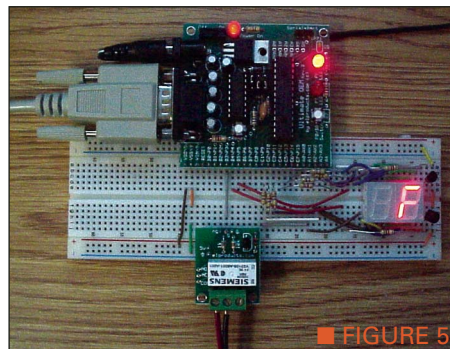


FIGURE 5

from 29 to 0 at a one second rate. This gave me more time to walk away and watch the rocket launch with a camera than a 9 to 0 count would allow. You could also have it count from 99 to 0 at a slower rate by just changing the software. The software creates the proper LED lighting format that forms the 0-9 digits. I also decided to add the letter "A" to the display options to indicate "Armed" and the "F" character to indicate "Fire." This was something the old design could not do.

As I mentioned earlier, the original design used an SCR as the switch to feed current to the rocket igniter. It would keep supplying power until you flipped the fire switch off. I decided to use a relay instead and put a time limit on the relay control. This way the software would shut down power after a few seconds, in case it didn't launch and someone raced up to the rocket to see what was wrong. This was another feature the original design did not have.

Rather than have several different switches, I let the software handle the different steps. The software will first light all the segments of the displays to prove there aren't any burned out segments. I do this by lighting all the segments of each display for one second and then off for one second. If I have any burned out LEDs, I can see it before I rely on a proper countdown display. Then I will have the software display the "A" in the 1's digit place and hold until it gets a signal from the momentary switch to start the countdown. When the switch is pressed, the software starts the countdown using nested For-Next loops until the count reaches zero. The relay is then turned on with a simple HIGH command followed by a five second pause and

then a LOW command to shut it off. The program jumps back to display "A" again and waits for a new switch press. Figures 3, 4, and 5 show the sequence of events.

HARDWARE DESIGN

The schematic is shown in Figure 6. I tried to highlight the key circuitry by making it bigger. The LED displays are common anode HDSP-5301s, but any common anode displays will work. The relay is a PCB mount DPDT type with 5V coil similar to Jameco 9938CK, but a SPST relay will also work fine as long as it has a 5V coil. I cheated again and used one of my Ultimate OEM modules along with a breadboard

version of the relay module. The relay module has an NPN transistor to ground the relay coil. The transistor is needed because the relay current is too high to drive from the PIC I/O pin directly. I also added a diode across the relay coil to absorb any inductive spike occurring when the coil is shut off.

The LEDs are both connected to the same set of I/O pins except for the common anode pins. Each common anode has its own PNP transistor to supply the power. By only turning on one display at a time, we can have the I/O drive the individual LEDs. If the software can switch between the two of them fast enough, the human eye cannot tell they were lit separately and they will look like they are lit together. This is multiplexing.

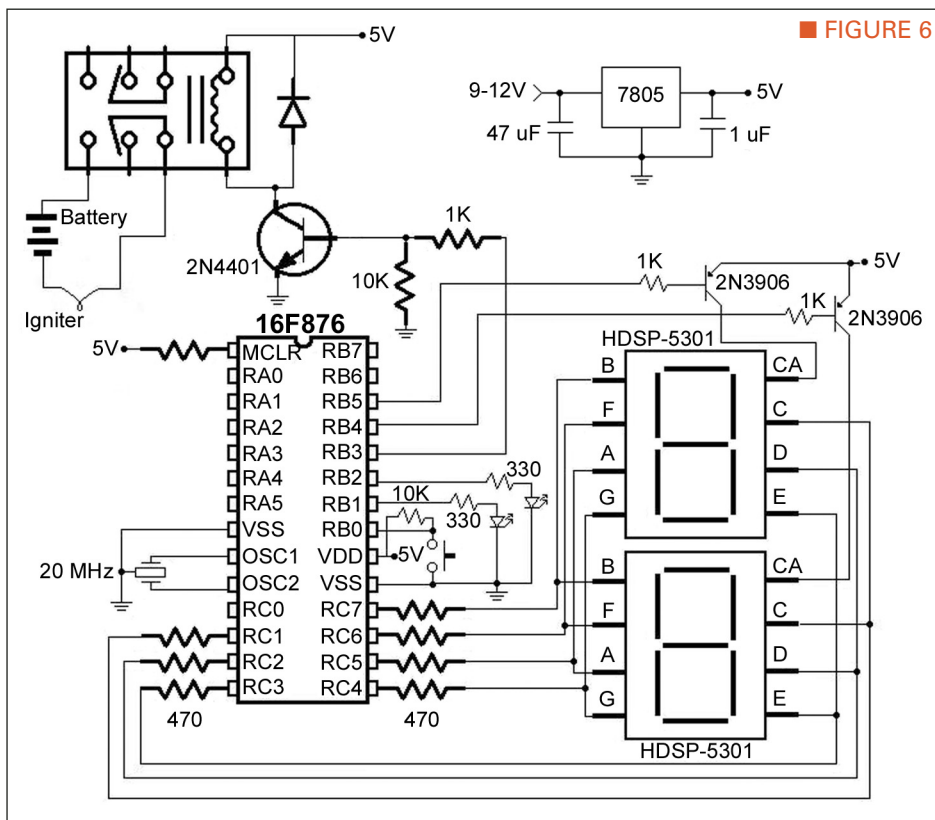


FIGURE 6

The indicator LEDs and momentary switch are built into the Ultimate OEM module but these could have easily been built into the breadboard. I ran the PIC at 20 MHz but 4 MHz would have been fine. If you drive more than two LEDs in multiplex mode, then you want more speed and 20 MHz makes it easier. Overall, the schematic is quite simple and easier to build than the high school design.

SOFTWARE

The software is more complicated than previous articles and will require the full version of PICBasic Pro. This can easily be run in Atom Basic but I haven't done that so I don't know exactly which commands may need syntax changes. I'll go through a few key parts. The program starts off by defining it for bootloader programming and a 20 MHz resonator.

```
DEFINE LOADER_USED 1  ' uses a bootloader
define OSC          20 ' 20 MHz resonator
```

Next, the various variables are set up for the display character routines.

```
CHAR10 VAR BYTE      ' 10's digit storage byte
CHAR01 VAR byte      ' 1's digit storage byte
X VAR BYTE            ' 1's digit index
Y var byte            ' 10's digit index
TIME var word         ' Multiplex timer loop counter
byte
```

The I/O is set up for proper startup mode where a "1" is an input and "0" is an output. I write directly to the PortB register.

```
TRISC = %00000000    'SET PORTC TO ALL OUTPUTS
PORTB = %00111000    'SET PORTB OUTPUTS LOW
TRISB = %00000001    'SET PORTB B1-B7 TO OUTPUT, B0
                     'INPUT
```

The display proveout routine simply controls the common anode transistors with HIGH and LOW commands. By driving the PortC register directly, the program will light any LED where a 0 exists and turn off any LED associated with a 1. Since we want to light all the LEDs, all the PortC pins are set to 0 and then finally all to 1 to shut them off. I also set both transistors off with a HIGH command.

```
' *** PROVEOUT THE DISPLAY ***
Init
low 5                'ENABLE LEFT LED
high 4
portc = %00000000    'ALL SEGMENTS ON left
pause 1000           'DELAY 1 SECOND

low 4                'ENABLE RIGHT LED
high 5
portc = %00000000    'ALL SEGMENTS ON right
pause 1000           'DELAY 1 SECOND

high 5               '10's LED OFF
high 4               '1's LED OFF
portc = %11111111    'ALL SEGMENTS OFF
pause 1000           'DELAY 1 SECOND
```

The main loop of code is next. The 1's digit (or right digit) is turned on and then PortC is set to display the letter A. The ready to launch LED is lit with a direct drive of the PortB bit 1 pin to a 1 or high state.

```
MAIN      '*** MAIN LOOP START ***
' *** SET DISPLAY TO "A" FOR ARMED AND PORTB LED ON FOR
'READY ***
low 4                '10's LED ON
high 5               '1's LED OFF
PORTC = $04          'DISPLAY "A" for Armed
PORTB.1 = 1          'READY LED ON
```

The program now goes into an If-Then loop that waits for the switch on PortB bit 0 pin to go low. It's pulled up to 5V through a resistor so it sits normally high. When it's pressed, the program moves to the launch label.

```
'*** TEST LAUNCH BUTTON ***
HOLD
if PORTB.0 = 1 THEN HOLD 'IF NOT PRESSED WAIT,
                        'OR MOVE TO LAUNCH
```

The launch mode starts off by turning off the launch ready B1 LED.

```
LAUNCH
PORTB.1 = 0          'READY LED OFF
```

The countdown is handled by two For-Next loops with another nested in between to create the roughly one second time delay. The program uses separate LOOKUP commands to convert the For-Next counter value to a proper LED setup that displays the numbers 0 through 9. I have them shown in Hex mode, but it's easier to understand them in binary mode. Take the first one "\$10" that forms the number "0," in Binary its %00010000. This means every segment is lit but one, which is the one tied to the B4 pin. That pin is connected to the "G" segment which is the segment we want off to display 0. See how easy the LOOKUP command makes displaying characters?

```
'*** LAUNCH MODE ***
For Y = 2 to 0 step -1      '10's COUNTDOWN LOOP
Lookup y, [$10,$7C,$42],CHAR10 ' 10's DIGIT SETUP

for x = 9 to 0 step -1      '1's COUNTDOWN LOOP
lookup x, [$10,$7C,$42,$48,$2C,$88,$80,$5C,$00,$08],CHAR01
'1's DIGIT
For time = 1 to 500        'Delay loop for 1 second
low 5                      'Enable 10's LED
HIGH 4
PORTC = CHAR10              'SEND 10's DIGIT NUMBER
VALUE TO DISPLAY
pause 1                    'Delay to see 10's LED
High 5                     'Enable right LED
Low 4
PORTC = CHAR01              'SEND 1's DIGIT TO DISPLAY
pause 1                    'Delay to see 1's LED
next
NEXT                        'GET NEXT 1's DIGIT NUMBER
NEXT                        'GET NEXT 10's DIGIT number
```


Notice how the 10's digit is displayed and then the 1's digit by controlling the B4 and B5 pins. There is only a one millisecond delay between the display actions so our human eyes cannot tell they are lit separately.

Finally, the For-Next loops end and the count is at "00." The program then drives only the 1's digit again and displays the F character with the value \$86 Hex.

```
low 4          '1's LED ON
HIGH 5         '10's LED OFF
PORTC = $86    'DISPLAY "F" for FIRE
```

The fire LED is lit on PortB bit 2 and the relay is turned on by setting PortB bit 3 high with a HIGH command. A PAUSE 5000 command leaves the relay on for five seconds. Then a LOW command shuts it off and turns the fire LED off.

```
HIGH 2         'Fire LED ON
HIGH 3         'TURN ON RELAY
PAUSE 5000     'DELAY 5 SECONDS
LOW 3          'TURN RELAY OFF
LOW 2          'FIRE LED OFF
```

As the last step, the program jumps back to the main label to set the whole thing up in the "armed" mode.

```
goto main
```

NEXT STEPS

I wanted to add a continuity check to the setup, but ran out of time. This is something I have to leave to the reader to add. My plan was to add a resistor across the relay output leads and then have an A/D port measure the voltage drop. This way I could read the value of the voltage to verify current was flowing through, but not enough to fire the igniter. When the relay closes, it shorts out the resistor and sends enough current to fire the igniter.

Also, using the external interrupt to stop the countdown should be easy to implement since the momentary switch is connected to the B0 external interrupt pin. I'll let you add this, also. You can add several relays to this design to control a timed Christmas light display.

CONCLUSION


Hopefully the project demonstrated how to drive LED displays in multiplex mode. Driving a relay is pretty straightforward after you see it done. This was a fun project; I just wish I had more time to expand it. I'll save the breadboard so I can expand on it myself in the future. I sure wish I had microcontrollers like this when I was back in my high school electronics classes. It

would have been a lot more fun. If you have any ideas for future articles, pass it on via email to chuck@elproducts.com. I don't get a chance to answer every email, but I try. I do read them all, so keep 'em coming. By the time you read this article, hopefully you will begin to see some of the changes I have planned for my website www.elproducts.com. I want to focus more on writing articles and books, so you'll see that I've arranged to have the hardware sales handled by other websites. I hope to have more sample code and helpful tips on my site that filling orders just would not allow me time to complete. Helping beginners get started programming PICs in Basic was always my plan for elproducts.com anyway.

This should also answer some of the complaints that I only write to sell my stuff. Selling books and writing the articles does help me keep my hobby going, but I write because I like to share the knowledge I've learned the hard way so others can share in the fun. I learned a lot from magazines and books when I was starting out with electronics and now it's time for me to give a little back. Thanks to *Nuts & Volts* and you, I can. See you next month. **NV**

ABOUT THE AUTHOR


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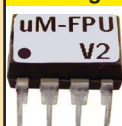
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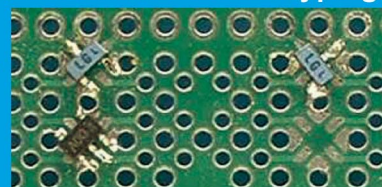
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READER FEEDBACK

Continued from page 50

technical as well as economic aspects: The heatsink is sold for \$1.75; Digi-Key sells the LM7805CT from Fairchild for \$ 0.48 (single quantities), so the additional ICs are cheaper than the heatsink. And you need less space (the TO-220s are much smaller than the heatsink), get more safety margin, and save money. You might even choose to use two to three external bypass transistors instead of the second and third 7805 ICs. Those sell for \$0.10 or less (select for the TO220 or similar case to get your 2W/piece dissipation), but chances are that you have a few suitable PNPs in TO220 laying around that you could use here at no extra cost. And if you should need more than 0.5A output current — well, just add a few 7805s or transistors.

I've learned that sometimes a not-so-elegant "brute force attack" may lead to a simpler solution than a well engineered one, but I recommend to do the engineering first (e.g., heat dissipation and heatsink calculation) and the brutality afterwards. Maybe some of your readers know other "unusual" solutions to typical problems. I would be glad to read about them in one of your future issues. Best regards to the whole NV team!

Thomas Ernst
Switzerland

SATISFIED READER

I subscribed to *Electronics Now* and *Popular Electronics* since finishing school in '88. I got onboard with *Nuts & Volts* when they both ceased publication. I thought they both were a bit more basic than N&V but it suited me just fine. Some of your articles are way over the top for me, but I realize that you must satisfy the more advanced hobbyist.

I really enjoyed the high altitude, near space experiments a few months back. Very interesting stuff and something all can participate in.

Overall, I'm satisfied with your publication. I feel it helps me stay on the edge of new developments.

Steve Anderson

FORMULA 411

In the July issue, the article on "Choosing a Heatsink" was very informative and provided good information that people need to know when choosing components for power supplies or other higher-powered applications. Good topic!

I just want to point out in Table 1 where the formulas for various dissipating devices are concerned that for a FET, particularly a power MOSFET, the power dissipation was listed as being $V_{gs} \times I_d$. This should actually be $V_{ds} \times I_d$ or $R_{ds(on)} \times I_d^2$. One of the shining attributes of an FET is the fact that the average gate current is almost negligible and so is its contribution to device dissipation; the drain-to-source junction, where V_{ds} takes place, is where the bulk of dissipation occurs.

Dan P.

ON THE RADAR

The Radar article was basically well written but it omitted the origin of the acronym RADAR — a word that was coined by Furth & Tucker of the US Navy in 1940 and was universally adopted by the allies in 1944.

Fifty microseconds is a very long pulse width for conventional radar use. One tenth of a microsecond was in use by some 1945 model tracking radars.

"Tracking the History of RADAR" published by the IEEE press is a good start on reading radar history. The IEEE website has several interesting oral histories online.

The Historical Electronics Museum just south of Baltimore has a wealth of info on radar and the history of electronics in general.

THAT institution deserves an article in N&V!

As for Vaughn Martin's statement about the unavailability of analog 'scopes on p. 98 — one ought to look at the ad on the inside back cover of the July issue of *Nuts & Volts*.

Don Helgeon
Gleaner & Scrounger for
ElectroHist & RadarHist Newsletters

A DMM MYSTERY SOLVED

I have an explanation of the experimental results that Paul Verhage discussed in his Near Space column.

First of all, consider how a DMM measures resistance. Most DMMs measure current by putting out a current that flows from one of the DMM leads, through the resistor to be measured, and back to the DMM again through the other lead. The DMM then measures the resulting voltage across the resistor.

As you can see, when you try to measure the resistance of a transistor with a DMM, the DMM injects a current into the transistor. The direction of the current depends on which DMM lead is connected to the collector and which is connected to the emitter. Most (possibly all) DMMs have the current leave the positive lead and return through the negative lead. So when you connect the positive lead to the collector and the negative lead to the emitter, you are injecting current into the collector. This is the 'normal' mode of operation.

When you connect the DMM's negative lead to the collector and the positive lead to the emitter, you are injecting current into the emitter. This is the 'inverted' mode of operation. This is not the true inverted connection; that's when the collector is grounded. But since you are injecting current into the emitter, it does qualify as a form of inverted operation.

The voltage measured from collector to emitter (in the normal mode) or from emitter to collector (in the inverted mode) is composed of two factors. One factor is the resistance and this voltage depends on the current flowing in the resistance. The other factor is the internal saturation voltage. In effect, there is a small battery in series with the transistor which is independent of current. Because of the internal saturation voltage, you cannot measure the resistance with a DMM and get meaningful data. The only way to measure the resistance portion of the voltage is with a delta method. It works

like this: At some known current, measure the voltage and again at some other known current. Subtract the two voltage readings and divide by the difference in the currents. That's the resistance. Knowing the resistance and the current, the difference between the measured voltage and the IR calculation is the internal saturation voltage.

Due to the difference in current gain, beta, in the 2N3904 in the normal mode vs. the inverted mode, the inverted mode internal saturation voltage is much lower than the normal mode internal saturation voltage. (Don't ask me for the details; I don't know them.) The resistance in the inverted mode isn't much different than that of the normal mode. As a result, the voltage drop is usually lower in the inverted mode. While the internal saturation voltage doesn't change with collector (or emitter) current, it does change with base current. As the base current is increased, the internal saturation voltage drops; at some current, it stops dropping and remains constant as the base current continues to be increased.

Some of the base current flows in the emitter (or collector) and causes an IR drop. This drop increases as the base current increases. Therefore, there are two opposing actions: an increase in the base current causes the internal saturation voltage to decrease, but causes the IR drop to increase. So the collector to emitter (or emitter to collector) voltage first decreases, then flattens out, then increases as the increase in the IR drop outweighs a further decrease (if any) of the saturation voltage.

So the data you collected shows that voltage drop is smaller in the inverted mode and first decreases, then flattens and then increases in both the normal mode and the inverted mode. It also showed the voltage drop is smaller in the inverted mode.

However, due to the presence of the internal saturation voltage, the DMM gave incorrect results for the actual resistance. The measured voltage is larger than the internal IR

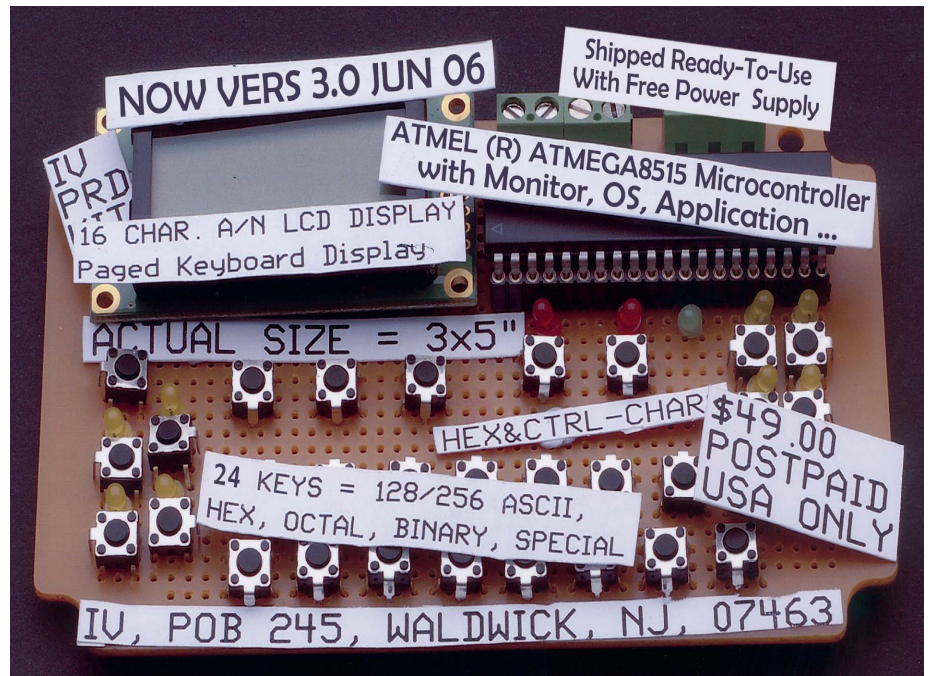
drop. This means that the transistor's actual resistances are lower than what's shown in the July Near Space column.

In a transistor data sheet, the specification for $V_{ce(sat)}$ at some current is the voltage measured at that current and includes the IR drop and the internal saturation voltage I've described above.

A transistor makes a good switch

in the inverted mode since the saturation voltage is much lower. Inverted bipolar transistor switches were frequently used in digital-to-analog converters made from discrete components long before IC D/A converters were available. Today, it's easy to implement CMOS switches which have pure resistance and no saturation voltage.

Stuart Michaels



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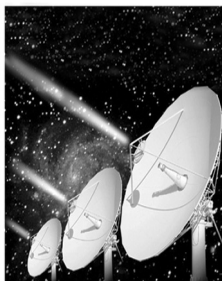
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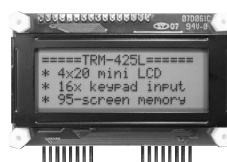
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TECH



FORUM

This is a READER-TO-READER Column.

All questions *AND* answers are submitted by *Nuts & Volts* readers and are intended to promote the exchange of ideas and provide assistance for solving problems of a technical nature. Questions are subject to editing and will be published on a space available basis if deemed suitable by the publisher. Answers are submitted by readers and **NO GUARANTEES WHATSOEVER** are made by the publisher. The implementation of any answer printed in this column may require varying degrees of technical experience and should only be attempted by qualified individuals. Always use common sense and good judgement!

All questions and answers should be sent by email to forum@nutsvolts.com All *diagrams* should be computer generated and sent with your submission as an attachment.

QUESTIONS

To be considered, all questions should relate to one or more of the following:

- ① Circuit Design
- ② Electronic Theory
- ③ Problem Solving
- ④ Other Similar Topics

■ Be brief but include all pertinent information. If no one knows what you're asking, you won't get any response (and we probably won't print it either).

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■ Include in the subject line of your email, the question number that appears directly below the question you are responding to.

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■ Comments regarding answers printed in this column may be printed in the Reader Feedback section if space allows.

>>> QUESTIONS

I have a 1989 Lincoln Town Car. I cannot play the AM radio due to excessive ignition noise. Any good suggestions for quelling this noise?

#8061

**Vincent Sariti
Wharton, NJ**

I have a Stanley remote controlled garage door opener model ST 500 that no longer responds to remote signals (two remotes). The batteries in the remotes have been replaced and code switches are set correctly. I have checked and reset the code switches on the receiver twice — no help. The opener works fine with the push button. Does anyone have a schematic of the radio signal receiver section (or other help)?

#8062

**Tyson Stephens
Banning, CA**

I have the sixteenth edition of *Transistor Substitution Handbook*, published by Howard Sam's Company in 1976. Over the years, this has been an invaluable aid when I wanted to sub a transistor using one from stock rather than racing to buy the expensive NTE subs.

It appears that books like this

are no longer in print. Do you know of a website database for this purpose?

#8063

**Stuart
Via email**

I want to build a 24 VDC power supply using the LM723 voltage regulator, at around 20-30 amps.

I can custom wind a large transformer for this project, but I need a schematic for the voltage regulation section. I would also like to know if I could use a power MOSFETs instead of a bipolar transistor like the 2N3055. I believe that using a MOSFET with a low on resistance should lower the heat generated. Does anyone have an idea or schematics to do this?

#8064

**Tim Henley
Thomasville, NC**

>>>> ANSWERS

[#6064 - June 2006]

I recently got hold of some junk laptops and was hoping to use the LCD monitors for other applications.

#1 Laptop LCDs are generally the least convenient kind to use. First, I'll suggest the easiest way I know of to use them. Assuming the laptop is "too

[#5062 - May 2006]

I need a log-scale level indicator using bipolar transistors.

Without using an integrated-circuit comparator, or an op-amp, there should be a method to make a bipolar transistor-based five-LED output VU or level display for an audio amp. In this case, though, I want the display to take its input at the pre-amp level signal as it is applied to a 10K volume pot, so that it indicates the level of input prior to the volume control, and so is independent of the volume control.

#1 I am not sure why the reader does not want to use an operational amplifier or another integrated circuit to create the log-scale level indicator requested. I suspect that the perceived problem may be the need for a dual supply of op-amps, typically ± 15 volts. However, we can find on the market today, op-amps that have been designed to operate as low as 3V, and also op-amps designed to function without a bipolar voltage source. Be careful here, as taking a "regular" op-amp and trying to make it work with a single voltage supply or at low voltage will not work.

There are a large number of designs for logarithmic amplifiers using one op-amp and a few transistors. One of my favorite reference sources for this type of circuits is a very practical book that was once published by Analog Devices:

Nonlinear Circuits Handbook. Analog Devices. January 1976. ISBN: 0-916550-01-X

It is hard to find, but if you contact Analog Devices they may still find some left. I got mine a few years ago directly from them. I was told that they

had some left as the book is out of print. This is a great book, published by one of the leading manufacturers of semiconductors — and it contains very practical circuits.

Finally, I want to point out that there are a large number of logarithmic amplifiers designed into ICs on the market today. The AD8304 from Analog Devices is a good example. You can find more types by going to www.analog.com and clicking on the link "Log Amps/Detectors" in the first column under the tab "Products."

Albert Lozano
Edwardsville, PA

#2 This is obviously a student project, since no one else would want to do this. I am not inclined to do anyone's homework, so I have

designed the circuit using ICs where needed (it is an interesting problem).

The input signal is calculated to be 67 mV p/p. 45 dB is a gain of 180; the maximum output is 12 volts p/p, $12/180 = .0667$. U1 amplifies the signal so that the offset of the comparators can be neglected. Only the negative swing of the signal at the op-amp output is used, so LED1 lights with the lowest level and LED5 lights with the highest level. I was lazy and used my slide rule to find the logarithmic increments for R6-R9 (Lazy indeed! -Ed). I have not built this but have carefully checked the resistor values. You may want to increase the value of R2 if the audio amp output clips before LED5 lights.

Russell Kincaid
Milford, NH

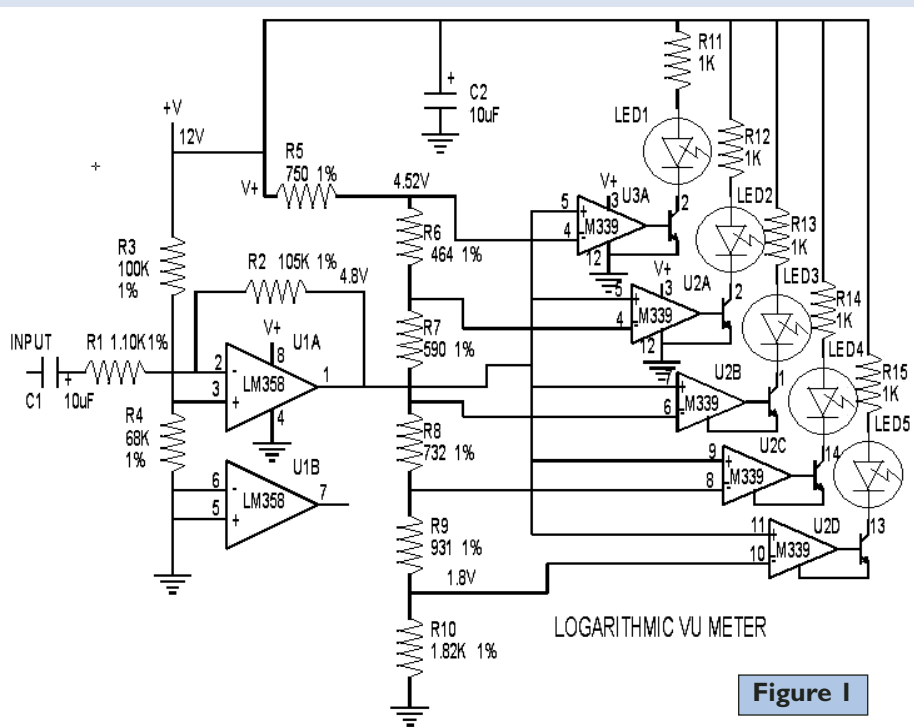


Figure 1

old" but still works somewhat, install MS-DOS on it and program it in QBASIC to display whatever you tell it to through the COM serial port. Second, I'll explain how I figure out the screen. Since you have "free" screens you obviously want to use them rather than buy recycled ones made ready for easy use. Try desperately to search the web for the datasheet. I recommend searching for TX36D86VC1CAB and either "pinout" or "pdf" or "datasheet." I did try it, but did not find

it within a reasonable amount of time. So, next I'd try turning on the laptops and probing all the wires. This is what they should be: *GND — This usually has large traces on the LCD and may be connected to the metal parts of the display. *+5V (or +3.3V) — This probably has a thicker trace than the rest except GND. *VLCD — Be careful with this, it may be specified as around 12 volts, either positive or negative to ground. *CE — This may either turn the screen off or make it ignore data (or

DE display enable). *Backlight power — maybe a separate isolated ribbon cable, probably ± 12 volts and maybe "off", may go to a high voltage inverter (ouch!) that lights up the backlight. *REDn, several wires digitally controlling the brightness of a pixel, one of which changes the redness of a pixel the most, the others by half, in order.

*GREENn, parallel digital brightness like RED but for Green *BLUEn, parallel digital brightness for blue pixels. Don't expect the color inputs to

actually be red, green, or blue colored wires.

*VERTICAL SYNC — This brings the pixels being controlled to the top line. (And possibly also the middle line!) *HORIZONTAL SYNC — This brings the pixel being controlled to the left side of the screen.

*HCLK — This moves to the next pixel, maybe called "pixel clock," some LCDs require four pixels at a time in parallel (may be called DCLK = dot clock).

(It may stop at the end of the line or continue halfway down the screen from the left side.)

By probing the wires of the ribbon cable with an O-scope or similar instrument, or perhaps by temporarily disconnecting each wire one at a time, you can guess what some of these are. Even an audio amplifier may give some clues. The Vertical Sync will be 60 Hz or higher. The Horizontal Sync will be around 16 kHz or even 32 kHz. The HCLK will be very fast — so fast, in fact, that if you cannot build a circuit that can read from memory to the RGB inputs at several megahertz rates without using up more processor clock cycles than you have available, you probably cannot use the laptop LCD screen at all. Experimental mis-driving can cause permanent damage to LCD screens, such as blackened or permanently-on pixels or lines. With neither a pinout nor semi-operational laptop, it's a colossal challenge. Simply put, laptop screens are equally hard to use in your project as spare picture tubes.

Search for "PIC TETRIS" to get a minimal idea of what it takes to "control" a video screen. (Rickard Gunee made some clever video games with just a PIC, joystick, and TV).

It will take a lot of time and effort, and success will be its own reward. It is sad that the manufacturers don't help much with pinouts, but I suppose that that would undermine their efforts to sell new flatscreens for thousands of dollars.

But fortunately, there are many other options if you want an LCD display. Look in *Nuts & Volts* for vendors of project-ready color graphic LCD modules that accept simple data, without requiring continuous synthesis of

video signals. Of course, they aren't very fast.

Some other options are surplus LCD TVs (which are analog compatible with TV cameras), and eventually used-but-working desktop LCD monitors (which may work with "legacy" VGA cards).

There is a flood of surplus simple text-only LCDs based on the HD44780 driver.

If you're still determined to drive the laptop screen well, here is what you have to do very fast:

BUS ON (video RAM address = fast binary counter)

READ NEXT BLOCK OF "VIDEO RAM" (including image and sync signals) INTO

LCD INPUTS

BUS OFF (tri-state)

BUS ON (processor)

CLOCK YOUR PROCESSOR

BUS OFF: REPEAT

CONTINUOUSLY

There is a function related to $X+Y \cdot K$ for calculating the bitmap memory address of a pixel for any specific display. I find it convenient to store the sync signals as uniquely "colored" pixels.

I improve the animation quality potential by switching between at least two banks of RAM, and only switching immediately after completely scanning the screen.

William Como
Bethpage, NY

#2 EarthLCD has several LCD controller boards: EarthLCD CNT-EV-GM2221 Controller — <http://store.earthlcd.com/s.nl/sc.7/category.99/it.A/id.4513/f>

They also have ISA and PCI bus interface boards — <http://store.earthlcd.com/s.nl/sc.7/category.108/f>

Daryl Rictor
Via the Internet

[#6065 - June 2006]

I have been very successful in using software to account for contact bounce in switches when designing digital microcontroller circuits. I recently read a statement in a book that said switch contact bounce could "easily be eliminated by the fitting of a small capacitor" into the circuit. I experi-

mented for hours using a variety of capacitors, but never came close to eliminating the contact bounce.

#1 A 10K resistor pulling up a switch that is paralleled with a 1 μ F or 10 μ F capacitor is usefully resistant to bouncing in logic circuits.

It can be improved by using Schottky buffers such as in a 40106 IC, which greatly reduces the chance of noise. Another method is to buffer with a monostable multivibrator, sometimes called a "one-shot" (perhaps for nervous trigger fingers?), which ignores noise for a settable time delay. That is a common use for an LM555 timer IC.

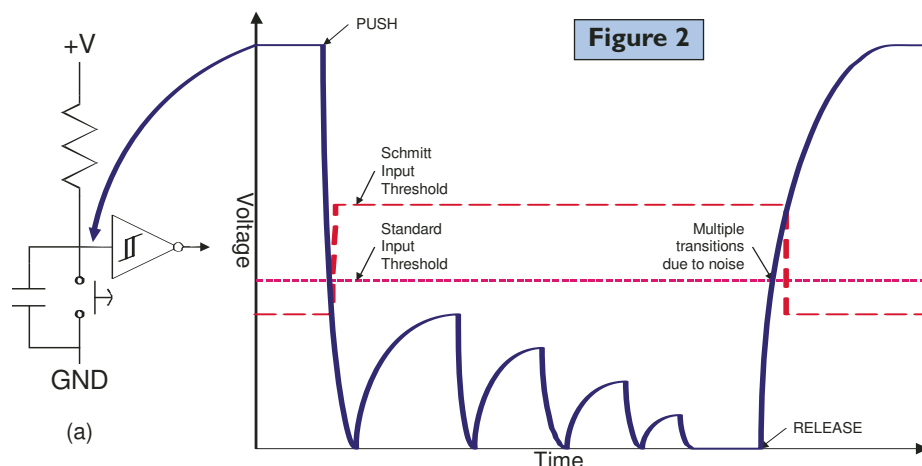
A perfect debounce is achievable with a three-wire switch (SPDT). Those are often called "microswitches" and are used for video game buttons. The moving pole of the switch is grounded, the two "on" positions are pulled up by 10K resistors, and input directly to SET and RESET inputs of a flip-flop. There is no need for timing and no bounce output, because the logic stays on until it goes all the way off, and stays off until it's all the way on. The advantage of this over the other way is that there is no confusion over whether the switch bounced or was intentionally pushed again rapidly.

William Como
Bethpage, NY

#2 Figure 2(a) is the traditional debounced push-button circuit. When the button is pushed, the capacitor is discharged to near zero very rapidly. Then, as the contacts separate during each bounce, it charges up slowly.

The RC time constant is chosen such that during the first bounce (the longest) the voltage never reaches the input threshold and thus the following digital circuitry never sees a one (the bounces still exist but they are just no longer significant).

The Schmitt trigger helps when the button is released. The capacitor charges up slowly (relative to the speed of the logic) and any noise present will generate multiple transitions as the capacitor voltage crosses the threshold of ordinary logic. The Schmitt trigger threshold drops when it is first exceeded and thus generates



a clean transition. Many microcontrollers have a few Schmitt trigger inputs which can be used for this purpose.

Though you can calculate the exact RC constant needed given the threshold and power supply, I don't as there is little penalty for using too large a capacitor. I tend to just use a rule of thumb and choose the resistor based upon the logic family (1K to 10K) and then compute a C that results in a 0.1 second constant (remember this is to charge it to 65% of the total) and then round down to the next available value [100 μ F to 10 μ F].

Figure 2(b) shows a way to invert the output. The voltages are just the inverse of the ones shown, with the exception that the threshold voltages remain the same. Since most thresholds are closer to ground than to the upper rail, Figure 2(b) can use smaller capacitors. It is interesting to note that the capacitor doesn't need to go across the push button, Figures 2(c) and 2(d) generate the same voltages as 2(a) and 2(b), respectively. It may just be more convenient to wire a project one way or the other.

JSB
Via email

[#7062 - July 2006]

I have a mini DV camcorder which came with a Lithium-ion 800 mA 7.4V power pack that lasts about an hour. The battery indicator has five dots to denote the capacity (five dots for 100% and three dots for 60% etc.). The indicator blinks when the battery drops below 20%.

I replaced the battery pack with a fully charged 6AA Ni-MH (1,800 mA 1.2V x 6). Immediately, the indicator started to blink. The battery lasts only 30 minutes.

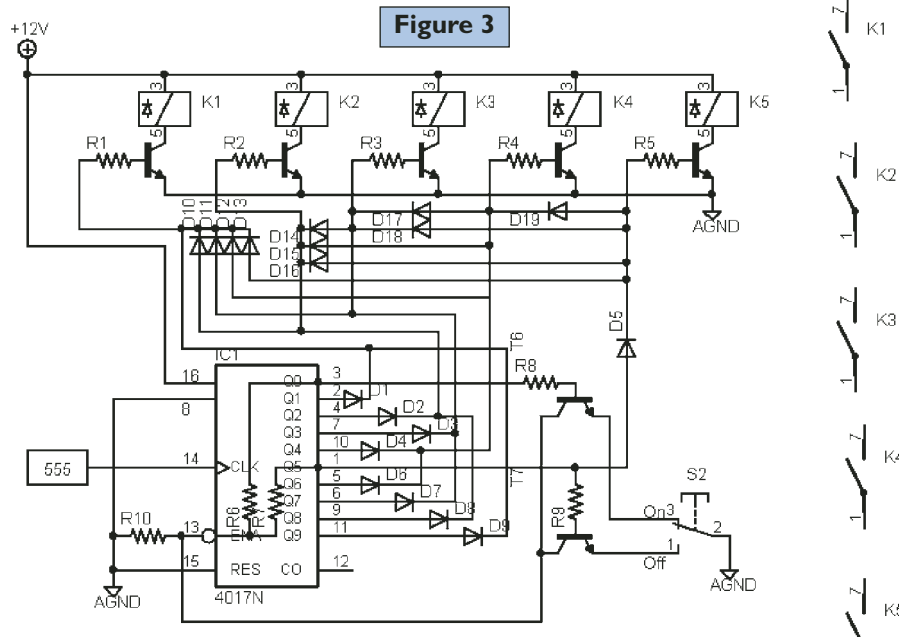
I'm afraid your camcorder's battery meter is calibrated for the Li-Ion battery's discharge curve. It starts at 7.6V and quickly drops to about 7.4V and runs steady for the hour. After that, the voltage will drop quickly after 90% of its charge is used. Your NiMH battery starts out at only 7.4V and drops to about 7.2V and runs more or less steady. However, the battery meter is calibrated to blink when the voltage drops below a set value and the NiMH battery falls below that threshold. The reason it quits after 30 minutes has to do with the shut-off

threshold. The Li-Ion will drop quickly at the end but the NiMH drops gradually over its discharge cycle. Its output drops below the shut-off threshold even though it has 50% of its charge still available.

Daryl Rictor
Via email

[#7063 - July 2006]

For several years now, I have been experimenting with a wireless intercom system that uses the ground for its medium. I have tried to transmit and receive voice frequencies only. I have had excellent success building receivers, but I'm having trouble getting my transmitters to go farther than a few hundred yards. My latest transmitter delivers 170V peak-to-peak swing straight to a copper pipe driven



about eight feet in the ground and still won't carry even half a mile. Heinrich Barkhausen in WWII spied on allied army field phones by hooking a sensitive audio amplifier to two poles driven in the ground. He picked up eddy currents from conversations miles away and was able to understand them. If he could pick up signals unintentionally induced into the ground, then why can't I find the secret to sending intentional currents into the ground to my cousin's house about two miles away? My goal is to have a two-way intercom between his house and mine.

Mr. Young did not specify exactly what the layout was regarding the copper pipes and how they were arranged. The transmitting and receiving pipe arrangement should be as follows. You will need two pipes for the transmitter and receiver locations. When you are standing at either location, and facing the distant location, you should have one pipe to your left and one pipe to your right. They should be at least 100-300 feet apart. You would then apply your 170 volt audio signal from one pipe to the other. In other words, connect one side of your audio circuit to one pipe and the other side of the audio circuit to the other pipe.

At the receiving end, connect one wire of your audio receiver to one pipe and the other wire to the other pipe. The audio signal currents will travel from one pipe to the other pipe, but will also radiate outward toward the receiving end. The farther apart you install the pipes, the farther the signal will transmit.

**John Reed
Richardson, TX**

[#7061 - July 2006]

I want to build a light timer/controller for a reef aquarium that would incrementally turn on a bank of fluorescent lights and/or metal halide lights in a specific order in the morning, then off in the opposite order in the evening. This would simulate the rise and fall of the sun. I need some manual control of the on/off process. I could use an array of individual timers from the hardware store, but that takes more room and outlets than I like. Can

something a little more compact and versatile be done with 555s or similar circuits? I don't want to use microcontrollers because of the extra complexity, programming, etc.

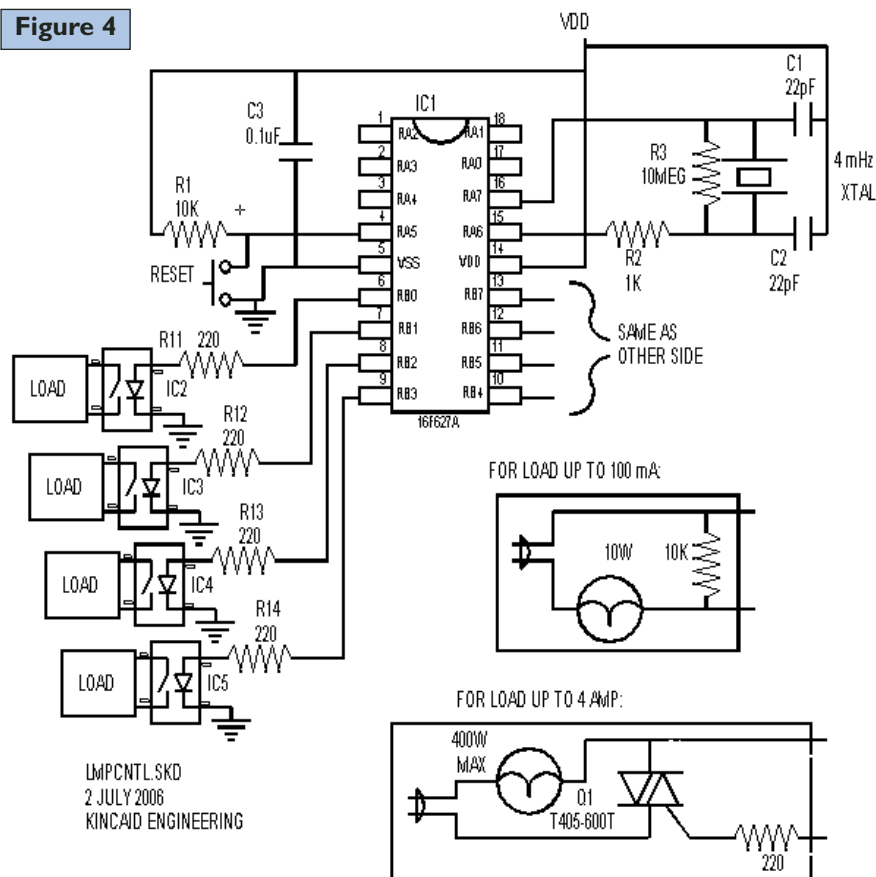
#1 A CD4017 decade counter feeding a diode matrix is just the ticket to incrementally sequence lights on, then decrementally sequence them off. The circuit in Figure 3 does that. The diodes are 1N4148, R1-R9 are 1K,

R10 is 10K. Select the relay with contacts rated to switch the load created by the aquarium lights. Put diodes reverse polarity across the relay coils, if they do not have diode protection built in as shown on the schematic.

How it works

Steering diodes gate the outputs from the counter to the appropriate relays such that the number of lights on equals the count when the count is

Figure 4



DAYLIGHT SIMULATOR PARTS LIST

Part	Description	Mouser.com Part Number
R1	10K, 5%, 1/4W	291-10K-RC
R2	1K, 5%, 1/4W	291-1K-RC
R3	1MEG, 5%, 14W	291-1M-RC
R11-R18	220Ω, 5%, 1/4W	291-220-RC
C1, C2	22pF, 5%, 50V ceramic	80-C315C220J1G
C3	0.1μF, 10%, 50V ceramic	80-C320C104K5R
XTAL	4MHz, parallel cut	815-AB-4-B2
IC1	PIC16F627A	579-PIC16F627A04P
IC2-IC9	MOC3023 opto triac	859-MOC3023
Q1-Q8	400V, 4A triac (snubberless)	511-T405-600T

Misc.

9 Pin male to 9 pin female serial cable	172-0906
EZPIC Programmer (available from www.elproducts.com)	
PICBASICPRO Demo software (available from www.melabs.com)	

below 6, and equals 10 minus the count when the count exceeds 5. The diodes are arranged so that the last light turned on is the first light turned off, then the next to last light turned on is the second light turned off, and so forth.

Two counts are special — 5 and 0. When the count equals either 0 or 5, the counter is frozen by making the enable pin (+), until switch S2 is operated. When the count is 0, all lights are off; when it is 5, all lights are on.

For fully automatic operation, a light sensing relay circuit can be used to replace S2. No duration was provided in the question, so build the timer to whatever spec you need.

**Ed Schick
Harrison, NY**

#2 Sunrise and sunset are slow operations, too slow for reliable 555 operation. You really need a micro-processor. The programming software can be downloaded for free, the PIC micro is low cost and the circuit is simple (see Figure 4). The programmer can be purchased from Chuck Hellebuyck for under \$30.

I chose the PIC16F627A because the free software supports it. PICBasicPro Demo only supports 31 lines of code. My program exceeds that, so the program would have to be trimmed to run the demo version. The PIC has 16 input-output ports but I only used eight. The program turns on a new lamp every 15 minutes (two hour sunrise and sunset). The lights stay on for eight hours, off for 12 hours. I used an external crystal; an internal oscillator is available but you would have to reset more often to synchronize the lights with actual daytime.

The Basic code is shown here in Listing 1 for your information, but I placed the HEX file on my website (www.geocities.com/russlk/daysim.txt). You just have to download it to your programmer. It is a text file, but the programmer wants to see .HEX, so you may have to rename it.

Make sure that you set the configuration bits in the PIC: XT oscillator, disable low voltage programming, and code not protected. If low voltage programming is not disabled, it will mess up the program. If the code is protect-

ed, the PIC cannot be re-programmed (and you may need to alter something). Sources for the needed

software and parts are in the parts list.

**Russell Kincaid
Milford NH**

```
*****
* Name      : daylight simulator (DAYSIM.BAS)
* Author    : [Russell Kincaid, Kincaid Engineering]
* Date      : 7/1/2006
* Notes     : This program turns on a lamp every 15 minutes to
*           : simulate sunrise. At the end of 2 hours, all
*           : lamps are on and stay on for 8 hours. At 10
*           : hours after starting, the lamps turn off in 15
*           : minute increments until all are off. The lamps
*           : stay off for 12 hours. PRESSING RESET WILL
*           : RESTART THE SEQUENCE
*****
' DEVICE = 16F627A
REM DISABLE LOW VOLTAGE PROGRAMMING, SET OSCILLATOR FOR XT
REM ENABLE RESET ON PIN#4 (RA5)
DEFINE OSC 4
PORTA = 0 : PORTB = 0
TRISA = %00010000
TRISB = %00000000
LAMP1 VAR PORTB.0
LAMP2 VAR PORTB.1
LAMP3 VAR PORTB.2
LAMP4 VAR PORTB.3
LAMP5 VAR PORTB.4
LAMP6 VAR PORTB.5
LAMP7 VAR PORTB.6
LAMP8 VAR PORTB.7
J VAR BYTE
T VAR WORD
START:
HIGH LAMP1
GOSUB DELAY15
HIGH LAMP2
GOSUB DELAY15
HIGH LAMP3
GOSUB DELAY15
HIGH LAMP4
GOSUB DELAY15
HIGH LAMP5
GOSUB DELAY15
HIGH LAMP6
GOSUB DELAY15
HIGH LAMP7
GOSUB DELAY15
HIGH LAMP8
GOSUB DELAY15
FOR T = 1 TO 32: GOSUB DELAY15: NEXT T
LOW LAMP8
GOSUB DELAY15
LOW LAMP7
GOSUB DELAY15
LOW LAMP6
GOSUB DELAY15
LOW LAMP5
GOSUB DELAY15
LOW LAMP4
GOSUB DELAY15
LOW LAMP3
GOSUB DELAY15
LOW LAMP2
GOSUB DELAY15
LOW LAMP1
GOSUB DELAY15
FOR T = 1 TO 48: GOSUB DELAY15: NEXT T
GOTO START
DELAY15:
FOR J = 1 TO 15: PAUSE 59380: NEXT J
REM Note: PAUSE changed from 60000 to account for overhead
RETURN
END
```

Listing 1

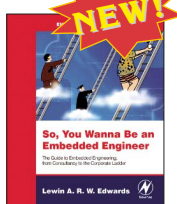
The Nuts & Volts Hobbyist BOOKSTORE

ELECTRONICS

So You Wanna Be an Embedded Engineer

by Lewin Edwards

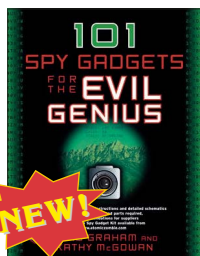
In this new, highly practical guide, expert embedded designer and manager Lewin Edwards answers the question, "How do I become an embedded engineer?" Embedded professionals agree that there is a treacherous gap between graduating from school and becoming an effective engineer in the workplace, and that there are few resources available for newbies to turn to when in need of advice and direction. This book provides that much-needed guidance for engineers fresh out of school, and for the thousands of experienced engineers now migrating into the popular embedded arena. **\$39.95**



101 Spy Gadgets for the Evil Genius

by Brad Graham/Kathy McGowan

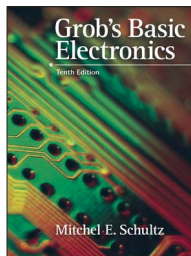
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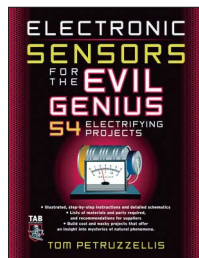
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by Thomas Petruzzellis

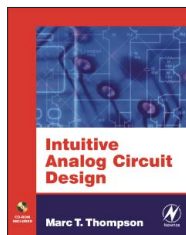
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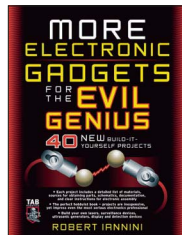
This book introduces analog circuit design with a minimum of mathematics. It gives readers an intuitive "feel" for analog circuit operation and rules-of-thumb for their design. The author uses numerous analogies from digital design to help readers whose main background is in digital make the transition to analog design. The application of some simple rules-of-thumb and design techniques is the first step in developing an intuitive understanding of the behavior of complex electrical systems. This book outlines some ways of thinking about analog circuits and systems that hopefully develops such "circuit intuition" and a "feel" for what a good, working analog circuit design should be. **\$59.99**



MORE Electronic Gadgets for the Evil Genius

by Robert E. Iannini

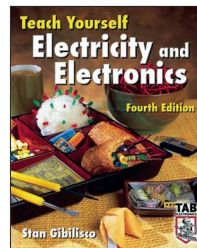
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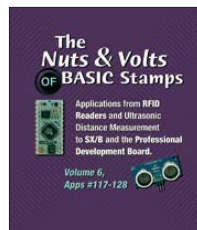


MICROCONTROLLERS

Nuts & Volts of BASIC Stamps — Volume #6

by Jon Williams

Nuts & Volts of BASIC Stamps — Volume 6 includes articles #117-128, written for 2005. Article topics consist of RFID Readers and Ultrasonic Measurement, SX/B and the Professional Development Board, the advanced MIDI receiver, programming the SX microcontroller in BASIC, mastering the MCI4489 display driver, and more! The Nuts & Volts of BASIC Stamps books are a favorite Parallax technical pick and are a tremendous technical resource for all PBASIC programming projects. **\$14.95**



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by David W. Smith

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- 12 kv acceleration voltage
- Sweep speeds to 2ns/Div.

Item# **6510****Limited Offer
\$519.00!**[Details at Web Site](#) > Test Equipment > Oscilloscopes/Outstanding prices**Protek 20MHz Dual Trace Oscilloscope**

- 20MHz Bandwidth
- Alt-Mag sweep for simultaneous display of main and X5 magnified trace
- 1mV/Div Vertical sensitivity
- Alternate trigger for a stable display of unrelated signals
- Multi-level trigger
- X5 Sweep Magnification

[Details at Web Site](#)

> Test Equipment > Oscilloscopes/Outstanding prices

\$279.00!**Protek 2MHz Sweep Function Generator**

- 0.02Hz-2MHz(7 Ranges)
- Sine, Triangle, Square, Pulse, Ramp, Slew Sine Waveform
- Sync. Out (TTL Square Waveform)
- Accuracy: $\pm 5\%$ of Full Scale to 200KHz, $\pm 8\%$ of Full Scale from 200KHz-2MHz
- Sweep Function
- VCG Input

Item# **PROTEK 9205**[Details at Web Site](#)

> Test Equipment > Function Generators

**Special
\$159.00!
Any Quantity****Digital Storage Oscilloscope Module**

PC based Digital Storage Oscilloscope, 200MHz 5GS/s equiv. sampling USB interface

Convert any PC with USB interface to a high performance Digital Storage Oscilloscope. This is a sophisticated PC based scope adaptor providing performance compatible to mid/high level stand alone products costing much more! Comes with two probes.

[Details & Software
Download at Web Site](#)

> Test Equipment > Oscilloscopes/Outstanding Prices

**Price
Breakthrough!**Item# **200DSO** Only **\$749.00****SONY Super HAD CCD Color Weatherproof IR Cameras**

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 480TV lines
- Min. Illumination: 0Lux

Item# **VC-827D: \$132.00**

SONY Super HAD CCD™ equipped camera's feature dramatically improved light sensitivity

SONY Super HAD CCD B/W Weatherproof IR Camera

- Day & Night Auto Switch
- Signal System: EIA
- Image Sensor: 1/3" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# **VC-317D: \$59.50**[Details at Web Site](#)**SONY Super HAD CCD Color Camera**

- Weather Proof
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 1Lux/F1.2

Item# **VC-805: \$53.95**

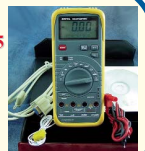
> Miniature Cameras(Board, Bullet, Mini's, B/W, Color)

Intelligent DMM w/ RS-232

- 3999 Counts and 38 Segment Bar Graph
- Dual Display (digits & bar graph)
- Capacitance Function, Transistor & Diode Test
- Frequency Range & Temperature
- RS232C Standard Interface
- Data Hold

[Details at Web Site](#)

> Test Equipment > Digital Multimeters/World Beater Prices

Item# **CS1345****SALE
\$29.95****SONY Super HAD CCD Color Weatherproof IR Camera**

- Day & Night Auto Switch
- Signal System: NTSC
- Image Sensor: 1/4" SONY Super HAD CCD
- Horizontal Resolution: 420TV lines
- Min. Illumination: 0Lux

Item# **VC-819D: \$62.50**

Visit our website for a complete listing of our offers. We have over 8,000 electronic items on line @ www.CircuitSpecialists.com. PC based data acquisition, industrial computers, loads of test equipment, optics, I.C.'s, transistors, diodes, resistors, potentiometers, motion control products, capacitors, miniature observation cameras, panel meters, chemicals for electronics, do it yourself printed circuit supplies for PCB fabrication, educational D.I.Y. kits, cooling fans, heat shrink, cable ties & other wire handling items, hand tools for electronics, breadboards, trainers, programmers & much much more! **Some Deals you won't believe!**

PropellerTM

Chip by Parallax, Inc.

What can you do with eight 32-bit processors (COGs) in one chip? Real simultaneous multi-processing! The new Propeller chip is the result of our internal design team working for eight years. The Propeller chip was designed at the transistor level by schematic using our own tools to prototype the product. The Propeller is programmed in both a high-level language, called SpinTM, and low-level (assembly) language. With the set of pre-built Parallax "objects" for video, mice, keyboards, RF, LCDs, stepper motors and sensors your Propeller application is a matter of high-level integration. Propeller represents the first custom all-silicon product designed by Parallax. *The Propeller is recommended for those with previous microcontroller experience.*

Propeller Chip Specifications

Power Requirements	3.3 volts DC
External Clock Speed	DC to 80 MHz (4 MHz to 8 MHz with Clock PLL running)
Internal RC Oscillator	12 MHz or 20 KHz
System Clock Speed	DC to 80 MHz
Global RAM/ROM	64 K bytes; 32K RAM / 32 K ROM
Processor RAM	2 K bytes each (512 longs)
RAM/ROM Organization	32 bits (4 bytes or 1 long)
I/O Pins	32
Current Source/Sink per I/O	50 mA

Propeller users have already been hard at work developing objects for the Propeller Object Exchange and discussing Propeller programming on our online forums. To join in visit www.parallax.com/propeller.

Propeller Chips	Stock Code	Price
P8X32A-D40 (40-Pin DIP) Chip	#P8X32A-D40	\$25.00
P8X32A-Q44 (44-Pin QFP) Chip	#P8X32A-Q44	\$25.00
P8X32A-M44 (44-Pin QFN) Chip	#P8X32A-M44	\$25.00
Propeller Tools	Stock Code	Price
Propeller Demo Board	#32100	\$129.95
PropSTICK Kit	#32310	\$79.95
Propeller Accessories Kit	#32311	\$99.00

To order online visit www.parallax.com/propeller. To order by telephone call the Parallax Sales Department toll-free at 888-512-1024 (Mon-Fri, 7 a.m. to 5 p.m., PDT).

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